PB98-107063

EVALUATION OF THE SCAN 16 EF ICE DETECTION SYSTEM

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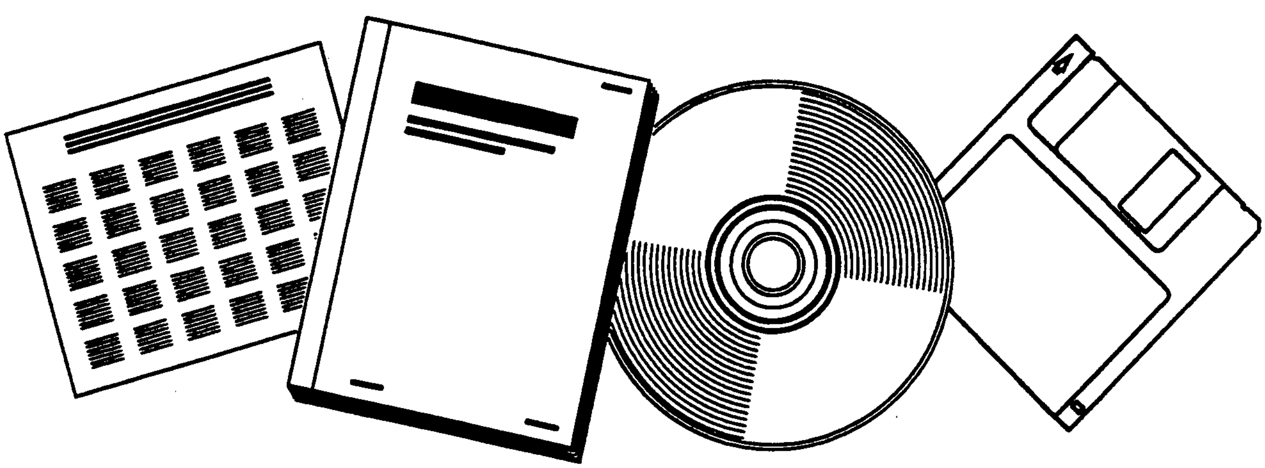

U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB98-107063

COMMONWEALTH OF PENNSYLVANIA
Department of Transportation

RESEARCH PROJECT NO. 89-065 A, B, and C

EVALUATION OF THE SCAN 16 EF ICE DETECTION SYSTEM

FINAL REPORT

April 1995

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BUREAU OF CONSTRUCTION AND MATERIALS

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Evaluations and Research Unit

16. Abstract

This report represents the details of construction as well as an Interim report based on the data provided for the winters of 1990-91 and 1991-92 for Research Project No. PA 89-65.

The pavement sensors are located in each of the four lanes of pavement on I-80 and they are connected by hardwire to the RPU (Remote Processing Unit). The RPU gathers and stores data from the pavement and atmospheric sensors and transmits this information via telephone line to the CPU (Central Processing Unit) at predetermined intervals. Technicians in the District 1 Office evaluate the data from the sensors and are able to give Maintenance personnel advance warning of impending icing conditions.

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Research Project No. 89-065
EVALUATION OF SCAN 16 EF ICE DETECTION SYSTEM

CONSTRUCTION
AND
INTERIM PERFORMANCE REPORT

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April 1995

CONDUCTED BY:

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
Bureau of Construction and Materials
Materials and testing Division
Engineering Technology Section
Evaluations and Research Unit

In Cooperation with
U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

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Metric Conversion Factors*

To Convert From:	To:	Multiply By:
Length		
foot (ft)	meter (m)	0.3048
inch (in)	millimeter (mm)	25.4
yard (yd)	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
Area		
square foot (ft^2)	square meter (m^2)	0.0929
square inch (in^2)	square centimeter (cm^2)	6.451
square yard (yd^2)	square meter (m^2)	0.8361
Volume		
cubic foot (ft^3)	cubic meter (m^3)	0.02832
cubic yard (yd^3)	cubic meter (m^3)	0.00315
gallon (U.S. liquid)	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
Mass		
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbm)	kilogram (kg)	907.2
Density		
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon(U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon(Can.)**	kilogram/cubic meter (kg/m^3)	99.78
Temperature		
deg Celsius (°C)	kelvin (°K)	$t^{\circ K}=(t^{\circ C}+273.15)$
deg Fahrenheit (°F)	kelvin (°K)	$t^{\circ K}=(t^{\circ F}+459.67)/1.8$
deg Fahrenheit (°F)	deg Celsius (°C)	$t^{\circ C}=(t^{\circ F}-32)/1.8$

* The reference source for information on SI units and more exact conversion factors is "Metric Practice Guide" ASTM E380.
** One U.S. gallon equals 0.8327 Canadian gallon.

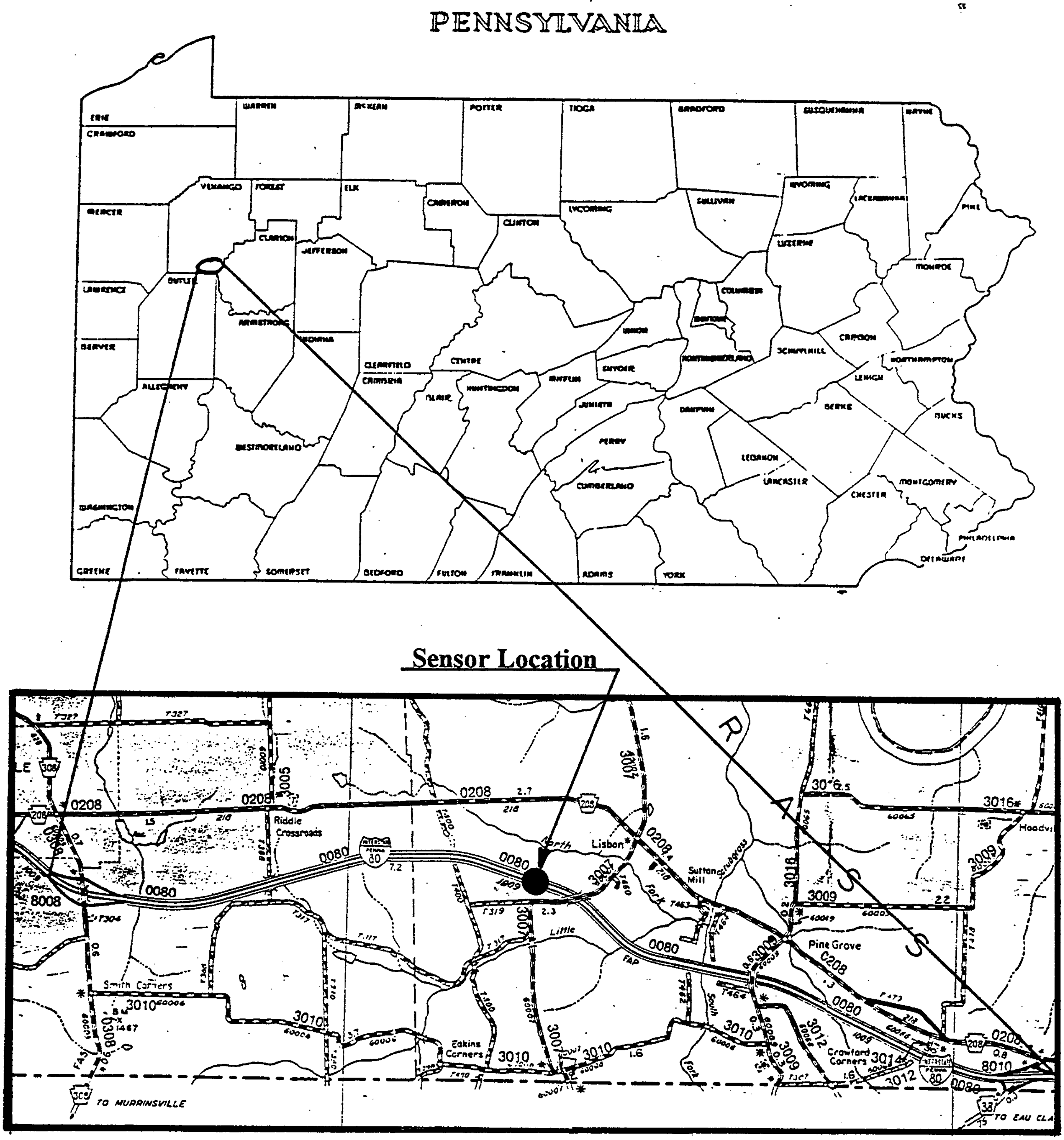


Figure 1 - I-80 Site Location Map
S.R. 0080 Segment 370 to 371
Venango County, District 1-0

INTRODUCTION

This report represents the construction and interim evaluation of the SCAN 16 EF ice detection system which has been operational in District 1-0 since January, 1990. It includes a description of the installation and construction and a tabulation of construction costs. The performance, during the winters of 1990-91 and 1991-92, of the constructed system is also evaluated in this report. The report also provides information pertaining to ongoing research and additional sites that have either been constructed or are proposed to be constructed in the near future.

SYSTEM DESCRIPTION

The SCAN 16 EF system was developed by Surface Systems, Inc. (SSI) of St. Louis, Missouri. The District 1-0 pilot installation defines surface and weather conditions for a section of Interstate 80 in Venango County. An at-grade sensor was installed in the concrete pavement in each of the eastbound lanes at Segment 370 and in each of the westbound lanes at Segment 371. Initially, three of the four sensors provided pavement surface data while the fourth monitored subsurface temperature through use of a subgrade probe.

The sensors are hard-wired to a Remote Processing Unit (RPU) housed in an enclosure adjacent to the site. Figure 3 on page 7 shows a typical highway Remote Processing Unit. Atmospheric sensors also monitor air temperature, dew point, wind speed and direction, relative humidity, and the occurrence of precipitation at each location. The sensor output is transmitted by modem to a Central Processing Unit (CPU) located at the District 1-0 headquarters in Franklin, PA. Figure 2 on page 6 shows a detailed layout of the SCAN 16 EF components and Figure 4 provides a detailed view of the CPU cabinet and equipment. Construction costs for the system totaled $118, 400, including the installation of the CPU and a micro-computer (PC) to access and process SCAN data. The placement of additional sensor groups will not require a duplication of the CPU, PC or system software.

System software was upgraded by SSI at no charge to the District during 1992 to enable additional sensor output to be processed from any selected site. Pavement surface data can now be processed from all four of the I-80 sensors with one of the sensors also continuing to provide subsurface temperatures.

PROJECT LOCATION

The SCAN 16 EF was installed as part of an interstate I-4R project (SR 80-A00) on I-80 in Venango County (See Location Map, page 1). The RPU is located on the south side of I-80 near Segment 370, Offset 2397. The sensors in the Eastbound lanes are located near Segment 370, Offset 1669 and near Segment 371, Offset 1632 in the Westbound lanes.

This location was selected because it historically has been a problem area for maintenance. This section of I-80 seemed to be the first area on the interstate that would freeze and cause icing problems.

CONSTRUCTION

The prime contractor for the project was Denton Construction Co. of Grousse Point, Michigan. The overall rehabilitation project began in April, 1989.

The rehabilitation included constructing high speed crossovers at each end of the project, switching traffic over to 1-lane, 2-way traffic in the westbound lanes, rubblizing the existing RCC pavement in the eastbound lanes, applying a bituminous leveling course to provide the proper cross slope and constructing an unbonded 13" Plain Cement Concrete Overlay with concrete shoulders. This work was then repeated for the opposing lanes.

After the contractor completed the rubblizing of the existing pavement, a trench was excavated across the eastbound lanes and a 4" PVC conduit was laid in the trench, with junction boxes at both ends. The conduit provides the path for the wiring from both the eastbound and westbound sensors. The RPU tower was erected on a site chosen by the Department based on its proximity to existing power and telephone service. The site is within the right-of-way but located a safe distance from the edge of the shoulder. A non-climbable aluminum tower consisting of two 10-foot sections was mounted on a 33"x 33"x 52" reinforced concrete pad (per manufacturer's specifications). The RPU unit was mounted on the tower along with instruments to measure: air temperature, wind speed & direction, relative humidity and dew point temperature. Underground conduit was laid from the RPU to the junction boxes installed at the sensors. Standard telephone and 100V AC electrical service was run to the RPU.

After the concrete pavement was placed, the sensors were installed by the contractor in October, 1989. A manufacturer's representative was present during installation. The following is a description of a typical sensor installation:

- The contractor drilled a 5" diameter core in each lane, in between the wheel tracks, to a depth of 1.5 inches. The core was then removed.

- A 4" deep, 9/16" wide saw cut was made from the core hole through the pavement and shoulder to the median.

- A foam backer rod was placed in the saw cut and the sensor cable was placed on top of the backer rod.

- A ground wire was wrapped around the sensor and then placed in the saw cut with the cable. The ground wire was then attached to an 8' long copper ground rod that was driven in the median.

- A foam backer rod was placed on top of the cable and ground wire.

- Three 1/2" diameter balls of epoxy material were attached to the bottom of the sensor. The sensor was then placed in the core hole and forced down until it was flush with the pavement surface. The epoxy balls were depressed beneath the sensor and served to level the sensor in the core hole.

- The entire circumference of the sensor was sealed with epoxy material.

- A 1" neoprene seal was placed in the saw cut, with the proper adhesive and lubricant, to within 1/8" of the pavement surface.

- The sensor cable was run to a junction box where splices were made to connect to the RPU.

The Manufacturer's Roadway Installation Manual is included in Appendix A of this report. Photos taken during the construction and installation process are included in Appendix B.

CONSTRUCTION COSTS

Because installation of the pavement sensors was not specified in Denton's original contract, this work was done by Force Account and handled as a Work order to the contract. A breakdown of the costs for materials and labor are listed in Table 1 and Table 2 below:

Table 1. - Total Costs

	Cost	Overhead Rate	Total Cost
Material Cost	$77,017.96	25%	$96,272.45
Labor Cost	10,274.21	40%	14,383.89
Equipment Cost	3,521.43	5%	3,697.50
SSI Site Visits	2,000.00	2%	2,040.00
Electrical Service	2,000.00	2%	2,040.00
	$94,813.60		$118,433.84

* Approximately $30,000 of the $77,017.96 Material Cost represents a one time purchase and would not be reflected in additional sensor sites.

Figures 2, 3, and 4 provide a pictorial representation of the SCAN System 16EF Ice Detection System and its components. Figure 2 shows the complete SCAN System including the RPU which is installed in the field to record field and atmospheric conditions, the CPU which is installed in the office to process information from the RPUs, and the terminal which provides access to SCAN data, weather forecasts, and radar. Figure 3 shows the RPU unit as installed in the field. It measures wind speed and direction, precipitation and amount, air temperature, relative humidity, and records data obtained from the roadway sensors. Figure 4 shows the CPU as installed in the office. It receives and processes information acquired from the RPUs via phone lines and provides a means for viewing that information.

Table 2. - Breakdown of Material Costs

	Quantity	Price	Amount
Remote Processing Unit (RPU)	1	$15,514.00	$15,514.00
Additional Tower Section, 10'	1	275.00	275.00
Atmospheric Sensor Package	1	4,330.00	4,330.00
Wind Speed & Direction Sensor	1	586.00	586.00
Surface Sensors, Model #16201D	4	3,337.00	13,348.00
Subsurface Temperature Probe	1	989.00	989.00
Splice Kit with Tools	1	197.00	197.00
Splice Kit with no Tools	4	35.00	140.00
Data Handler, Model # CPU/09	1	18,151.00	18,151.00
Color Printer, HP Paint Jet	1	1,364.00	1,364.00
IBM 50Z Personal Computer	1	6,188.00	6,188.00
Scan Color Software	1	4,014.00	4,014.00
WSI Color Access Software	1	2,800.00	2,800.00
Direct Burial Cable	4,500 LF	0.60	2,700.00
#8 AWG UF Electrical Cable	100 LF	0.50	50.00
1" PVC Conduit	100 LF	0.60	60.00
Class A Concrete (8CY min)	8 CY	65.00	520.00
Copper Clad Ground Wire, 1/2"x 10'	8	17.00	136.00
Copper Ground Rod Clamps	8	1.75	14.00
Rubber Bushing	1	50.00	50.00
Fused NEMA 3R Disconnect	1	110.00	110.00
1" Direct Burial PVC	200 LF	0.60	120.00
JB12 Junction Boxes	2	450.00	900.00
14 AWG Copper Ground Wire	1 Roll	23.50	23.50
3" PVC Conduit	6 LF	2.75	16.50
4" PVC Conduit	50 LF	0.23	11.50
1" PVC Couplers	30	0.65	19.50
1" PVC Elbows	5	0.75	3.75
1" PVC 90's	3	2.15	6.45
4" PVC Couplers	5	4.25	21.25
			$72,658.45
		6% Sales Tax	4,359.51
			$77,017.96

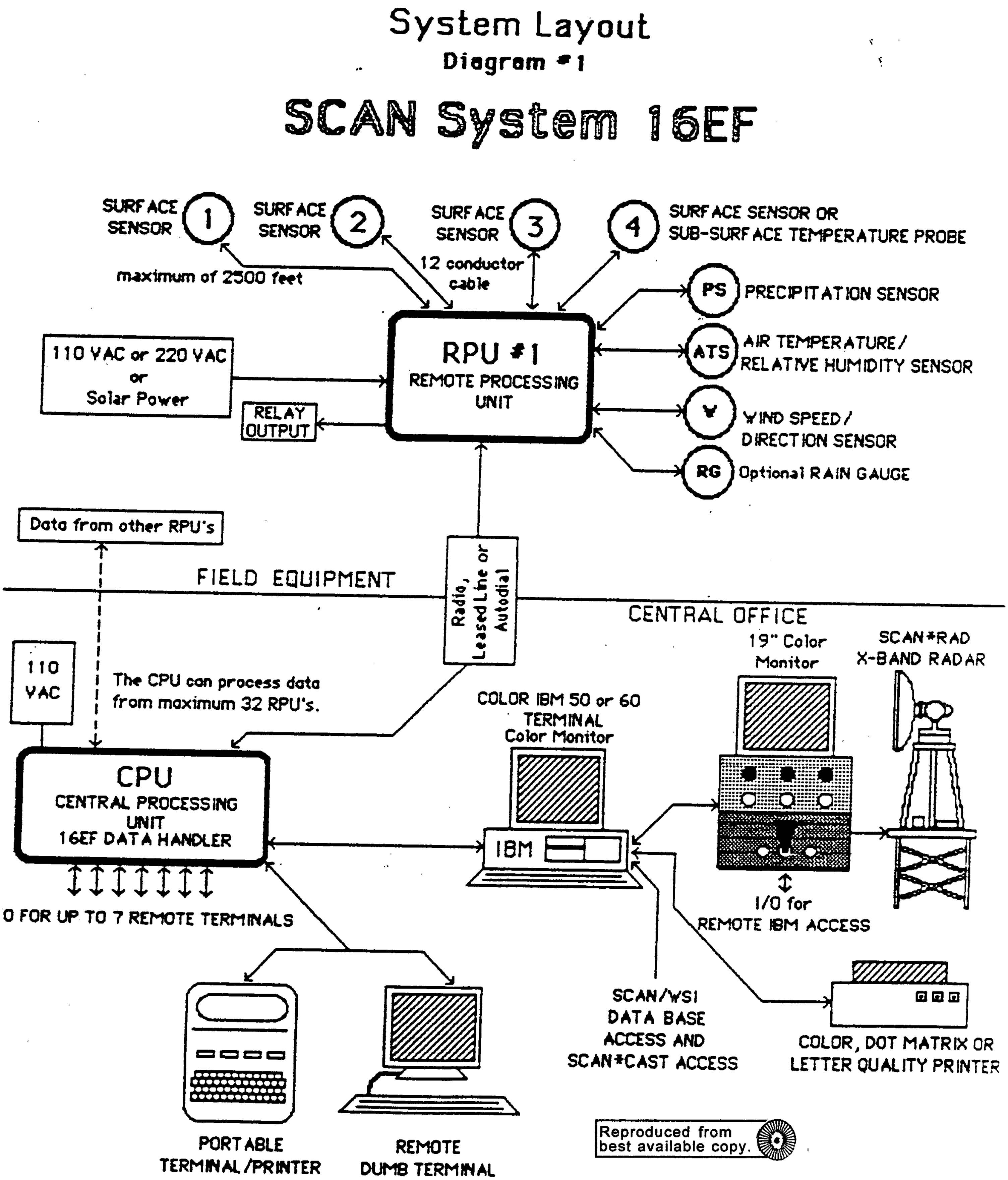


Figure 2 - System Layout for SCAN 16 EF

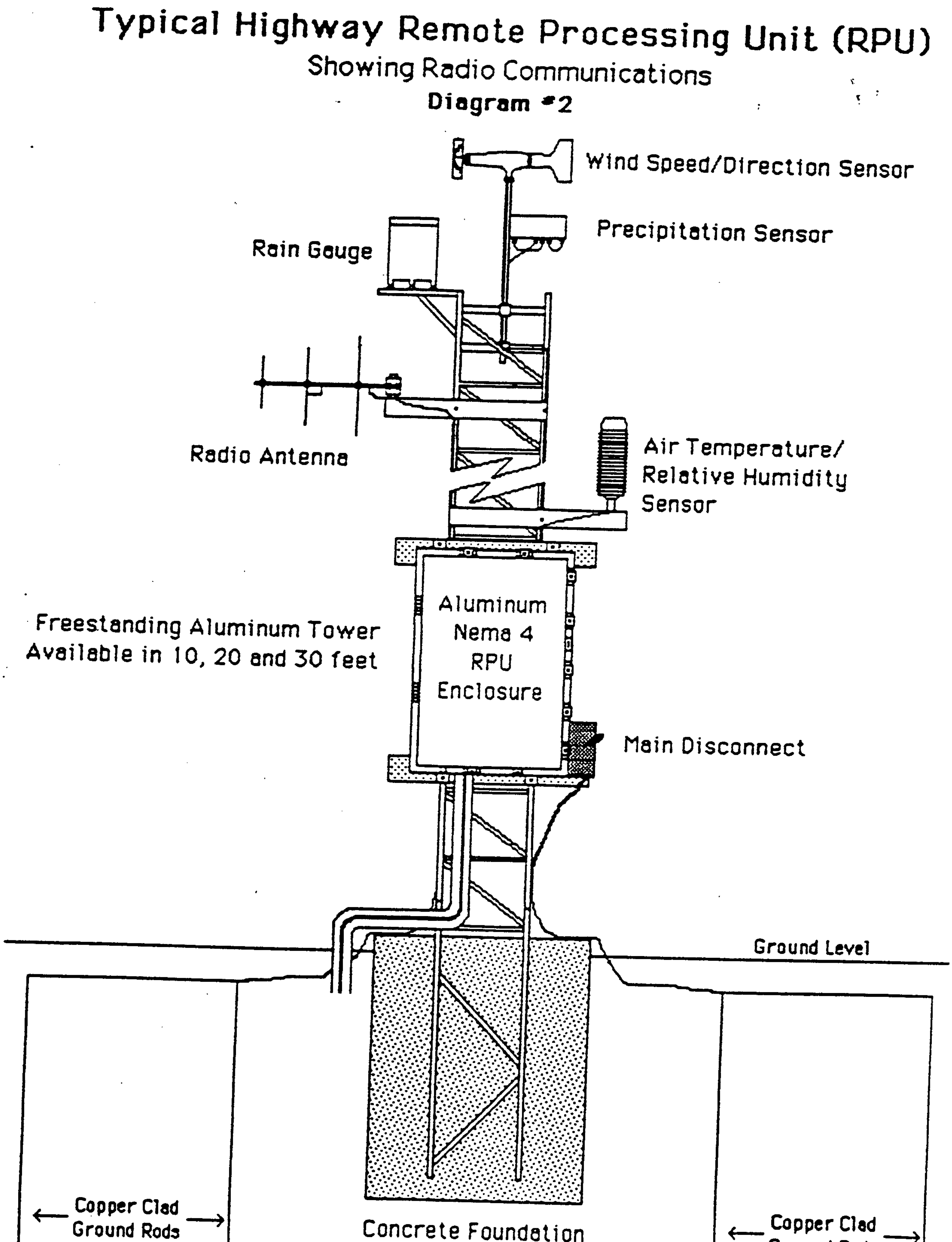


Figure 3 - Typical Highway Remote Processing Unit (RPU)

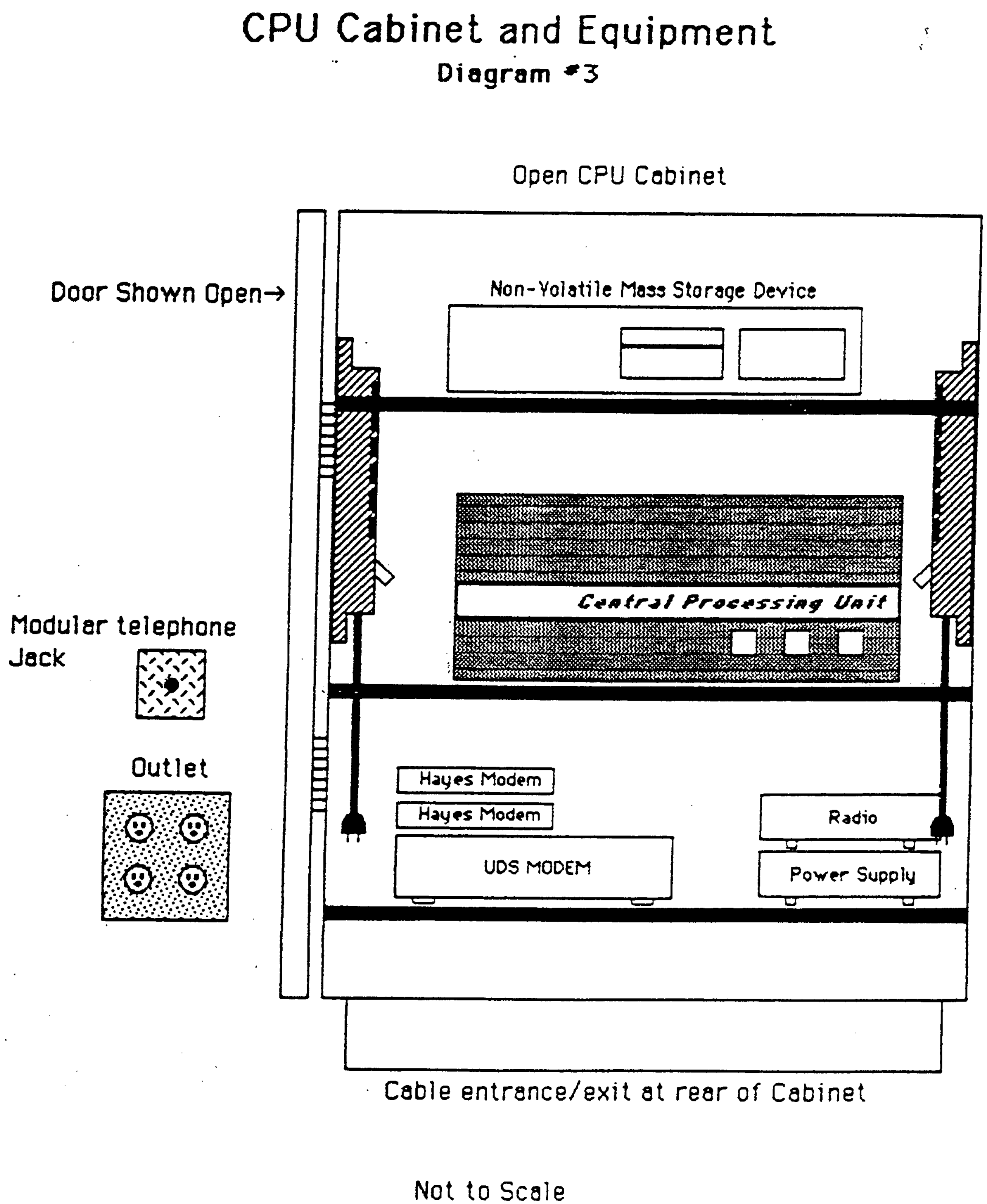


Figure 4 - CPU Cabinet and Equipment

OPERATING COSTS (1990-1991)

Current billings indicate that on site electrical charges for operation of the RPU average $24.00 per month during the winter season or $120.00 for the five month period November, 1990 through March, 1991. Electrical services for operation of the CPU and PC within the District office are estimated at an additional $120.00 for the same period.

- Electrical total (1990-1991) = $120.00 + $120.00 = $240.00

Long distance charges incurred in the transfer of data from the RPU on site to the CPU in Franklin totaled an estimated $2,300 for the 1990-91 winter season, involving nearly 300 calls per month. (Connect charges were included with construction costs.) Parameters have been established such that calls are initiated by the RPU every fifteen minutes when possible icing conditions are detected. If sensor output remains unchanged and weather conditions are favorable, data are updated on an hourly basis only. Calls can be initiated from the CPU on a less frequent basis using the District's WATS line.

- Long distance charges (1990-1991) = $2,300

•Total operating Costs (1990-1991):

$ 240.00 + $2,300.00 **<u>$ 2,540.00</u>**

OPERATING COSTS (1991-1992)

Current billings indicate that on site electrical charges for operation of the RPU averaged $36.50 per month during the winter season or $182.50 for the five month period November, 1991 through March, 1992. Electrical services for operation of the CPU and PC within the District office are estimated at an additional $120.00 for the same period.

- Electrical total (1991-1992) = $182.50 + $120.00 = $302.50

Long distance charges incurred in the transfer of data from the RPU on site to the CPU in Franklin totaled an estimated $2,500 for the 1991-92 winter season. Parameters have been established such that calls are initiated by the RPU every fifteen minutes when possible icing conditions are detected. If sensor output remains unchanged and weather conditions are favorable, data are updated on an hourly basis only. Calls can be initiated from the CPU on a less frequent basis using the District's WATS line.

- Long distance charges (1991-1992) = $2,500

Failure of one of the I-80 sensors entailed the following replacement costs. The work was performed in October, 1991 by Department forces.

Replacement sensor (under warranty)	$ 0.00
Labor	$ 1,600.00
Bit for core drill	$ 200.00
36-inch pipe wrench	$ 148.00
•Total	$ 1,948.00

•Total operating Costs (1991-1992):

$ 302.50 + $ 2,500.00 + $ 1,948.00 **$ 4,750.50**

Operation of the system did not require the hiring of any new employees. Data are monitored by maintenance dispatchers as an additional work activity.

ACCURACY AND RELIABILITY

System accuracy was evaluated for the 1990-1991 and 1991-1992 seasons by correlating visual pavement inspections with simultaneous data transmitted by the RPU. The observations confirmed that information provided by the system continues to be highly accurate with respect to both atmospheric and pavement conditions. The system has consistently performed well under varying weather conditions. Regular communication breakdowns as well as failure of components have, however, compromised the reliability of the system on several occasions.

System reliability has been compromised by the following component breakdowns: (1) Replacement of one of the I-80 sensor was discussed above; (2) Warranty replacement of the CPU was required in June, 1990 resulting in a loss of early historical data; (3) CPU failure in June, 1991 after nearly one month, non-critical down time; (4) A third CPU failure in January, 1992 that resulted in a more critical shutdown of eight days. It was determined that the recurring failure of the CPU's hard drive was most likely caused by power surges and/or inadequate ventilation. The CPU was replaced under warranty and an uninterruptable power supply and a ventilated cabinet, were both provided at no cost by SSI.

Random communications failures involving the interruption of modem transmissions have occurred on the average of four to five hours per week since the system's installation. These failures have been considered more a nuisance than a problem and no real attempts have been made to determine the cause.

BENEFITS

The evaluation and estimation of benefits for the 1990-1991 and 1991-1992 winter seasons were based on a review of historical data stored by the CPU, daily operator logs and maintenance payroll records.

Typically, two equipment operators from the Venango County Clintonville stockpile are responsible for winter maintenance along the pilot section of I-80 and savings noted have been based on two operators and trucks only. Material prices, overtime rates and equipment costs were provided by Venango County Maintenance:

<u>Prices for Winter season 1990-1991</u>

- Average material spread rate = 5 tons/hour/truck
- Target mix ratio = 50/50 anti-skid/salt (I-80)
- Anti-skid = $5.78 per ton
- Salt = $34.75 per ton
- One truck/operator/material = $153.73 hourly (w/overtime)
- Two trucks/operator/material = $307.46 hourly (w/overtime)
- Material only = $201.76 hourly (two trucks spreading)
- Average overtime call out duration = 4 hours
- Average length of storm = 10 hours

<u>Prices for Winter season 1991-1992</u>

- Average material spread rate = 5 tons/hour/truck
- Target mix ratio = 50/50 anti-skid/salt (I-80)
- Anti-skid = $6.40 per ton
- Salt = $33.29 per ton
- One truck/operator/material = $174.00 hourly (w/overtime)
- Two trucks/operator/material = $348.00 hourly (w/overtime)
- Material only = $198.45 hourly (two trucks spreading)

Similar conditions were identified in quantifying both the 1990-1991 and 1991-1992 winter benefits. These conditions include:

-Condition #1 - Monitoring of pavement sensors confirmed that no call out of maintenance crews was required due to pavement temperatures remaining above 32° F. A minimum average call out of four hours was used to quantify overtime and material savings noted.

-Condition #2 - Monitoring of pavement sensors resulted in a delayed call out or early dismissal of maintenance crews. Overtime and material savings resulted for the reduction in hours indicated.

-Condition #3 - Proactive monitoring of pavement sensors resulted in the early response of maintenance crews and the early application of salt. When de-icing chemicals can be spread prior to ice buildup or bonding to the pavement surface, experimental data suggest that up to 90% less material will be required over a storm's duration. Based on reduced equipment passes and spread rates, a 25% material reduction was applied for proactive responses noted on I-80. The reductions were applied for the storm durations indicated.

-Condition #4 - Monitoring of surface temperature and "chemical factor" (CF)* resulted in the application of less salt/anti-skid due to residual material from previous equipment passes. This may occur in storms of lengthy duration or when a severe ice buildup requires heavy initial spread rates. A 25% material reduction was also applied for the periods of consistently high CF values shown.

The occurrences of precipitation within the county and an estimate of SCAN benefits have been summarized in the tables on pages 13-15. Records for each storm were reviewed to determine which of the conditions shown best typified sensor data provided by the system.

*Chemical factor - Relative indication of the amount of salt in solution on the pavement surface based on data transmitted by the RPU regarding moisture present when the pavement surface temperature is at or below 32° F.

Winter Precipitation 1990-1991 Venango County

Date		Condition[1]	Savings	
November				
11-2-90	(No call out)	#1	4 hrs. X $307.46=	$1229.84
December				
12-03-90	(No call out)	#1	4 hrs. X $307.46=	$1229.84
12-03-90	(During shift)	#4	2 hrs. X $201.76=	$403.52
12-04-90	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
12-15-90	(No call out)	#1	4 hrs. X $307.46=	$1229.84
12-23-90	(No call out)	#1	4 hrs. X $307.46=	$1229.84
12-24-90	(Proactive)	#3	10 hrs. X $201.76=	$504.40
12-27-90	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
12-30-90	(Delay call out)	#2	2 hrs. X $307.46=	$614.92
12-31-90	(During shift)	#4	3 hrs. X $201.76=	$605.28
January				
01-03-91	(During shift)	#4	3 hrs. X $201.76=	$605.28
01-04-91	(Proactive)	#3	10 hrs. X $201.76 X 25%=	$504.40
01-05-91	(Proactive)	#3	10 hrs. X $201.76X 2S%=	$504.40
01-08-91	(Proactive)	#3	10 hrs. X $201.76 X 25%=	$504.40
01-09-91	(Sensor output not a factor)			
01-11-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
01-12-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
01-13-91	(Sensor output not a factor)			
01-14-91	(Sensor output not a factor)			
01-17-91	(No call out)	#1	4 hrs. X $307.46=	$1229.84
01-20-91	(Delay call out)	#2	2 hrs. X $307.46=	$614.92
01-22-91	(Sensor output not a factor)			
01-23-91	(One truck only)	#2	4 hrs. X $153.73=	$614.92
01-25-91	(During shift)	#4	2 hrs. X $201.76=	$403.52
01-27-91	(Sensor output not a factor)			
01-29-91	(No call out)	#1	4 hrs. X $307.46=	$1229.34
01-30-91	(Delay call out)	#2	2 hrs. X $307.46=	$614.92
01-31-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
February				
02-10-91	(No call out)	#1	4 hrs. X $307.46=	$1229.84
02-11-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
02-14-91	(Sensor output not a factor)			
02-17-91	(One truck only)	#2	4 hrs. X $153.73=	$614.92
02-25-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
02-26-91	(Sensor output not a factor)			
02-27-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
March				
03-01-91	(No call out)	#1	4 hrs. X $307.46=	$1229.84
03-03-91	(No call out)	#1	4 hrs. X $307.46=	$1229.84
03-05-91	(Sensor output not a factor)			
03-07-91	(No call out)	#1	4 hrs. X $307.46=	$1229.84
03-09-91	(Proactive)	#3	10 hrs. X $201.76X 25%=	$504.40
03-10-91	(Delay call out)	#2	1 hr. X $307.46=	$307.46

Estimated Total Savings (1990-1991) = $24,255.26

① See pages 11 and 12 for description of conditions #1 through #4

Winter Precipitation 1991-1992 Venango County

November

Date		Condition[①]	Savings	
11/08/91	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
11/11/91	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
11/12/91	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
11/13/91	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
11/24/91	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
11/26/91	(Proactive)	#3	(9 hrs. x $198.45) X 25% =	$446.51
11/27/91	(Sensor output not a factor)			

December

12/02/91	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
12/03/91	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
12/04/91	(Proactive)	#3	(12 hrs. x $198.45) X 25% =	$595.35
12/04/91	(High CF)	#4	(12 hrs. x $198.45) X 25% =	$595.35
12/05/91	(Sensor output not a factor)			
12/06/91	(Proactive)	#3	(8 hrs. x $198.45) X 25% =	$396.90
12/15/91	(Delay call out)	#2	2 hrs. x $348.00 =	$696.00
12/15/91	(Proactive)	#3	(17 hrs. x $198.45) X 25% =	$843.41
12/16/91	(Sensor output not a factor)			
12/17/91	(Proactive)	#3	(7 hrs. x $198.45) X 25% =	$347.29
12/18/91	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
12/21/91	(Proactive)	#3	(10 hrs. x $198.45) X 25% =	$496.13
12/23/91	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
12/28/91	(Sensor output not a factor)			
12/29/91	(Delay call out)	#2	2 hrs. x $348.00=	$696.00
12/30/91	(No call out)	#1	4 hrs. x $348.00=	$1392.00

January

01/07/92	(Sensor output not a factor)			
01/09/92	(Sensor output not a factor)			
01/10/92	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
01/11/92	(Proactive)	#3	(7 hrs. x $198.45) X 25%=	$347.29
01/12/92	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
01/13/92	(Sensor output not a factor)			
01/16/92	(Sensor output not a factor)			
01/17/92	(Proactive)	#3	(15 hrs. x $198.45) X 25% =	$744.19
01/19/92	(Sensor output not a factor)			
01/28/92	(Sensor output not a factor)			
01/30/92	(Proactive)	#3	(18 hrs. x $198.45) X 25% =	$893.03
			Subtotal pg. 14	$22,757.45

① See pages 11 and 12 for description of conditions #1 through #4

Winter Precipitation (cont'd.)

February

Date		Condition[1]	Savings	
02/04/92	(High CF)	#4	(6 hrs. x $198.45) X 25%=	$297.68
02/05/92	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
02/07/92	(High CF)	#4	(6 hrs. x $198.45) X 25%=	$297.68
02/08/92	(Delay call out)	#2	2 hrs. x $348.00 =	$696.00
02/11/92	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
02/13/92	(Proactive)	#3	(20 hrs. x $198.45) X 25% =	$992.25
02/14/92	(High CF)	#4	(18 hrs. x $198.45) X 25% =	$893.03
02/15/92	(Sensor output not a factor)			
02/16/92	(High CF)	#4	(7 hrs. x $198.45) X 25%=	$347.29
02/18/92	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
02/19/92	(High CF)	#4	(6 hrs. x $198.45) X 25%=	$297.68
02/20/92	(Sensor output not a factor)			
02/22/92	(Proactive)	#3	(3 hrs. x $198.45) X 25%=	$148.84
02/25/92	(Sensor output not a factor)			
02/28/92	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
02/29/92	(Proactive)	#3	(3 hrs. x $198.45) X 25%=	$148.84

March

03/06/92	(Sensor output not a factor)			
03/07/92	(Sensor output not a factor)			
03/11/92	(Proactive)	#3	(22 hrs. x $198.45) X 25% =	$1091.48
03/12/92	(High CF)	#4	(10 hrs. x $198.45) X 25% =	$496.13
03/13/92	(Proactive)	#3	(8 hrs. x $198.45) X 25%=	$396.90
03/14/92	(Proactive)	#3	(2 hrs. x $198.45) X 25%=	$99.23
03/15/92	(Proactive)	#3	(7 hrs. x $198.45) X 25%=	$347.29
03/17/92	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
03/18/92	(High CF)	#4	(6 hrs. x $198.45) X 25%=	$297.68
03/20/92	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
03/21/92	(High CF)	#4	(7 hrs. x $198.45) X 25%=	$347.29
03/22/92	(Delay call out)	#2	4 hrs. x $348.00 =	$1392.00
03/22/92	(High CF)	#4	(16 hrs. x $198.45) X 25% =	$793.80
03/26/92	(Sensor output not a factor)			
03/27/92	(Delay call out)	#2	3 hrs. x $348.00 =	$1044.00
03/30/92	(No call out)	#1	4 hrs. x $348.00 =	$1392.00
03/31/92	(Sensor output not a factor)			

Subtotal this page	$19,125.09
Subtotal page 14	$22,757.45
1991-1992 Estimated Savings	**$41,882.54**

① See pages 11 and 12 for description of conditions #1 through #4

Note, the estimated savings shown are relatively conservative as the following factors have not been considered:

① Savings were based on two operators/trucks only, yet information provided by SCAN was used to gauge conditions for the entire southern portion of the county and savings could easily be projected to include additional operators/trucks.

② Prior to implementation of the SCAN system, it was necessary for county personnel to visually inspect pavements for an evaluation of surface conditions. The availability of SCAN data has effectively reduced the corresponding mileage and overtime costs and allows an immediate reaction to conditions as they change.

③ Indirect savings from improved public perception and driver safety as a result of better response times are difficult to quantify. Maintaining a proactive rather than a reactive response during the winter season will reduce the number and severity of accidents as well as the potential for tort liability. A single accident can result in thousands of dollars of economic loss.

④ As SCAN operators grow more aware of system capabilities, the surface "chemical factor" can be further used to limit equipment passes and material application when CF values remain consistently high. Material mix ratios could be adjusted according to CF output.

⑤ Reduced salt and anti-skid usage will lengthen the service life of pavements and bridge decks and reduce equipment maintenance costs. It will also reduce spring cleanup efforts and environmental damage.

⑥ The escalation of material prices and wages will result in additional savings.

COSTS & BENEFITS SUMMARY

The following is a comparison of operating costs vs. estimated SCAN savings for the 1991-1992 and 1990-1991 winter seasons. Estimates for 1989-1990 have not been compiled as the system was operational for a portion of the winter only. A review of weather trends, county overtime costs and material usage at the Clintonville stockpile for the evaluation period is included as Appendix D.

Winter 1989-1990

Cost Details	Insufficient Data

Winter 1990-1991

Estimated Savings	$24,255.26
SCAN Operating Costs	$3,540.00
Net Savings	$20,715.26
Number of Occurences of Wet Pavements	41

Winter 1991-1992

Estimated Savings	$41,882.54
SCAN Operating Costs	$4,750.50
Net Savings	$37,132.04
# of Occurrences of Wet Pavements	67

ADDITIONAL SENSOR SITES

Six additional sensor groups have been installed in District 1-0. A location map designating these sites is shown as Figure 5, Page 22. Site 1 is the original site constructed in October 1989 and evaluated under this research project number, 89-065 A. Sites 2, 3, 4 and 5 are sites that were constructed in the fall of 1992 and are to be evaluated by District 1-0 personnel under research project number 89-065 B. Site 6 was constructed and is online and operating effectively and will also be evaluated under research project 89-065 B. Seven sites located in Districts 10-0, 2-0, 3-0, 4-0, and 5-0 have been constructed completing the Interstate 80 corridor study and will be evaluated as part of the Interstate 80 corridor study under research project 89-065 C. (See Figure 6, Page 21 for location of I-80 Corridor Sites). The continued evaluation will be completed by District personnel and the Bureau of Maintenance and Operations.

Site 5 (SR 0027) was added at the request of Venango County Maintenance based on performance of the system to date. Funding for this site will involve a 100% state allocation only.

CONCLUSIONS

The SCAN 16 EF ice detection system is an excellent complement to the District's Color Weather Radar operations and regional weather services. The system continues to provide accurate and timely information for the management of shift activities and snow removal crews.

Inquiries for I-80 sensor data are regularly logged from Venango, Mercer, and Clarion counties. As other sensor groups are placed, data will also be relevant for maintenance districts in Crawford, Erie, Forest, Warren, McKean, Butler, and Lawrence counties as well as state agencies in bordering counties of Ohio and New York.

Overtime, material and equipment savings of nearly $68,000 were estimated for the Clintonville stockpile over the 1990-1991 and 1991-1992 winter seasons. Direct savings occur when:

- The call out of snow removal crews can be delayed or avoided due to the confirmation of non-freezing pavement conditions.
- Material application can be limited through the prevention of an initial ice buildup or when consistently high CF values are noted.

The savings are only related to one stockpile. Although not measured, additional savings were realized at other locations which also used the sensor information to determine appropriate storm response.

Benefits including accident prevention, liability protection, longer service life for pavements, reduced environmental damage and an improved perception of PennDOT are intangible but should also be considered to properly evaluate the system's cost / benefit performance. It would not be possible to accurately predict or quantify indirect savings resulting from these benefits.

From the evaluation completed thus far, the SCAN 16 EF ice detection system appears to be a very useful and promising tool for the winter maintenance crews. The system allows personnel to be managed more efficiently and results in a savings in material usage. By using this ice detection system there will not only be savings realized by the Department but the safety of the traveling public is also enhanced.

Even though the evaluation of this one site has shown great promise, it only provides data and benefits for an isolated case, therefore additional sites have been added to this research project for further evaluation of the system. Five additional sites were added in District 1-0 as shown on the location map on page 19. These five sites have been constructed and are on-line. In addition to those five sites, seven new sites on I-80, have been constructed. These sites will provide data for the I-80 corridor study. Site 1 will be evaluated under research project 89-065A. Sites 2, 3, 4, 5, and 6 will be evaluated under research project 89-065B. The I-80 corridor study will be evaluated under project number 89-065C. This configuration will provide a complete evaluation of the SCAN 16 EF ice detection system.

Two year operating costs, primarily long distance charges, totaled more than $7,000 and costs to operate the system exceed $25,000 per year when projected to include additional sites. Methods to reduce excessive telephone charges should be further researched. Establishment of a statewide microwave communications network which could be linked to all sensor sites has been proposed as a possible long term solution.

Overall, the system has performed consistently well under a variety of weather extremes, although a number of component breakdowns were noted (See page 10). For operation of a multi-site system, a qualified Department employee should be adequately trained by SSI to perform component and software maintenance. System down time could be minimized and the cost of maintenance and repair of the system would be minimized.

Additional Evaluation

Due to the subjective nature of the four call out scenarios and the relative cost savings of each another method of evaluation was attempted. Climatological data was obtained from the National Oceanic and Atmospheric Administration (NOAA) to determine the occurrences of frozen precipitation and eliminate the strength of winters as a year to year variable. Data from three reporting stations were averaged and yearly totals were obtained. These data were compiled and is summarized in Table 5. The number of occurrences of frozen precipitation was recorded from the NOAA reports and data concerning the use of material (anti-skid and salt) and hours of plowing and spreading were obtained. The total yearly material use was then divided by the number of incidences of frozen precipitation to obtain a use per incidence figure. It was hypothesized that the amount of material used and number of man-hours spent plowing should decrease after the Ice Detection system was installed but this was not the case. The data showed an increase in both salt and anti-skid usage and an increase in man-hours after the ice detection system came on-line. This result raises a question with the method of evaluation and effectiveness of the ice detection system in reducing material usage.

It should also be noted that variability exists in the number of incidences of frozen precipitation, in decisions made by different county managers, and in the length and intensity of each storm. There is also a noticeable decrease in material per incidence for the winter 1993-94 and this decrease could be noted in further evaluation of the system after operators and managers become more familiar and secure with the system. A continued evaluation with the other sites and this criteria should be suggested to provide empirical data to support the cost savings indicated by the four call-out scenarios.

The following table shows the data obtained from the NOAA and District 1-0 Maintenance personnel. It shows the winter under evaluation, the total number of incidences of frozen precipitaion, the number of tons of anti-skid used, the number of tons of salt used, the number of hours spent plowing and spreading, and three columns showing these quantities per incidence of frozen precipitation.

Table 5 - Summary of Precipitation and Material Usage Data

Winter	Number of Incidences of frozen precipitation	Anti-skid (tons)	Salt (tons)	Plowing and Spreading (hours)	Anti-skid per incidence	Salt per incidence	Plowing and spreading per incidence
1981-82	70	27,105	10,057	N.A.	390	145	N.A.
1982-83	49	15,615	4132	N.A.	322	85	N.A.
1987-88	72	20,136	7161	16,511	282	100	231
1988-89	48	18,701	5976	14,070	387	124	291
1989-90	60	22,808	8537	17,247	382	143	289
1990-91	47	18,307	6412	12,219	390	136	260
1991-92	50	22,233	7819	17,803	445	156	356
1992-93	54	32,034	10,219	20,931	593	189	388
1993-94	72	27,042	9535	19,722	375	132	273

Note : Climatological data was not available for the winters 1983-84 thru 1986-87.

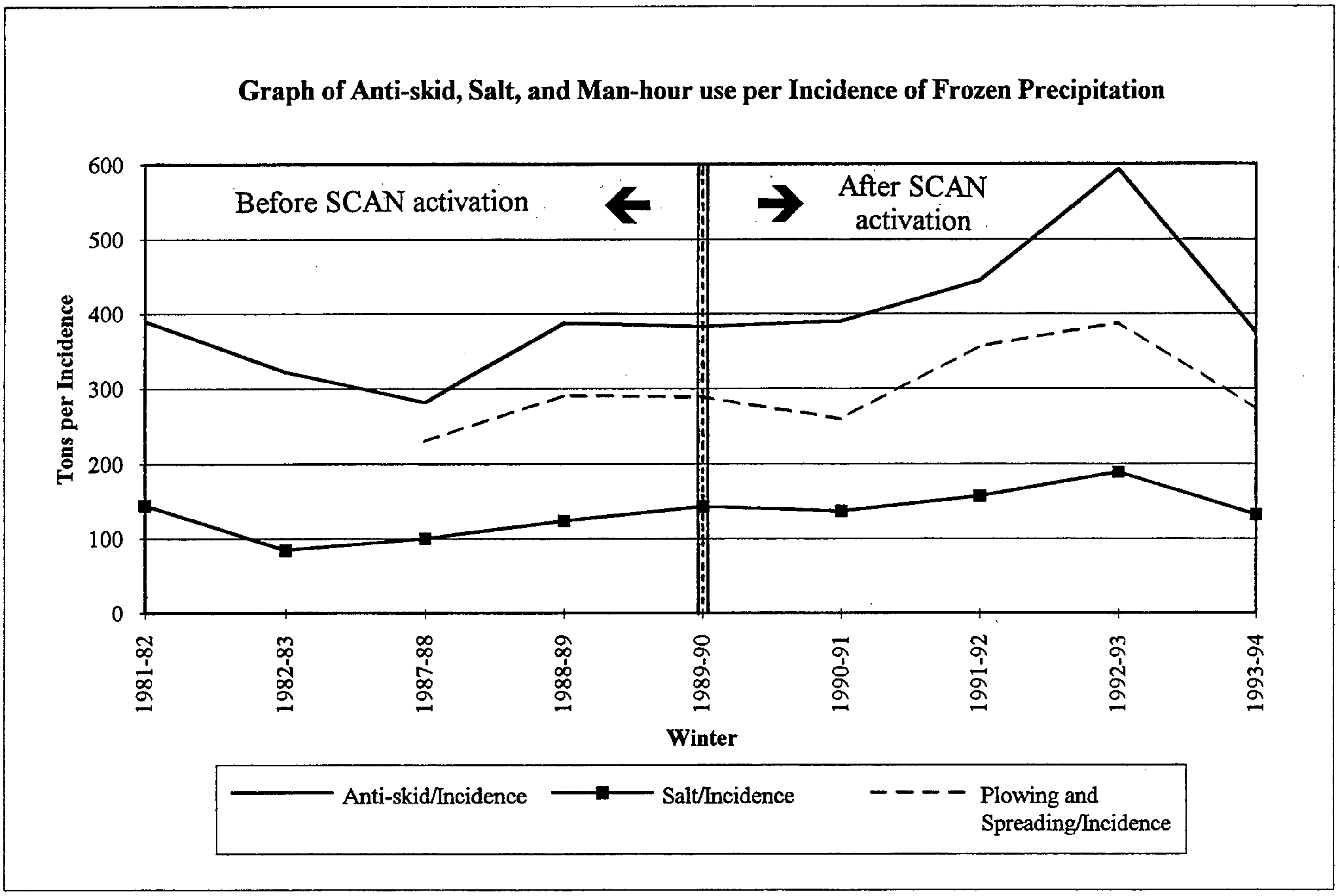


Figure 5 - Graph showing comparison of material
and man-hour usage before and after ice detection installation

PROJECT SUMMARY

The directive of the work plan was to evaluate the SCAN 16 EF system through the 1991-1992 winter season. Based on the trial I-80 configuration:

- SCAN accurately defined pavement and weather conditions from a remote location on a real-time basis.

- SCAN remained operational for more than 90% of the period January, 1990 through March, 1992.

- SCAN has demonstrated a potential to increase driver safety as well as provide material, overtime and equipment savings.

- Acceptance of the SCAN program was reinforced by Mr. William McQuiston, Assistant Venango County Maintenance Manager, "We didn't realize how much we relied on the SCAN sensors until the week the system was down" (January, 1992 CPU failure). It is felt that if reliability can be maintained, the proposed additional sensor groups will compound the savings and benefits noted to date.

- The estimated savings generated by the SCAN system enabled the district to amortize the cost of the system within two years.

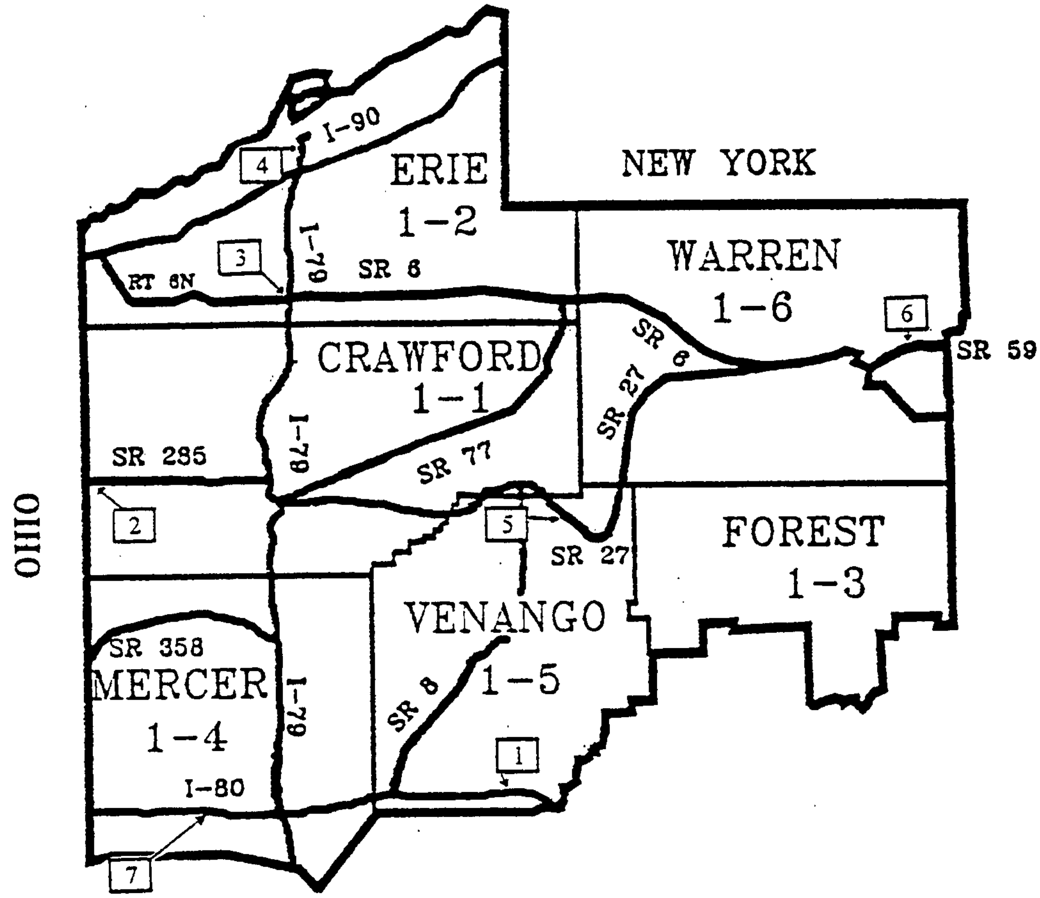
- SCAN data is transmitted over the Departments own AM radio transmitter near the Ohio line to advise motorists of roadway conditions across Pennsylvania on I-80.

- School District Administrators regularly contact the CPU dispatchers for up to date roadway condition reports.

- Other State Agencies can intercept the Department's SCAN data with the proper software.

- The SCAN system is an invaluable tool when used in conjunction with the District's Color Weather Radar System to close time and coverage gaps in weather forecasters from both the National Weather Service and private regional weather information providers.

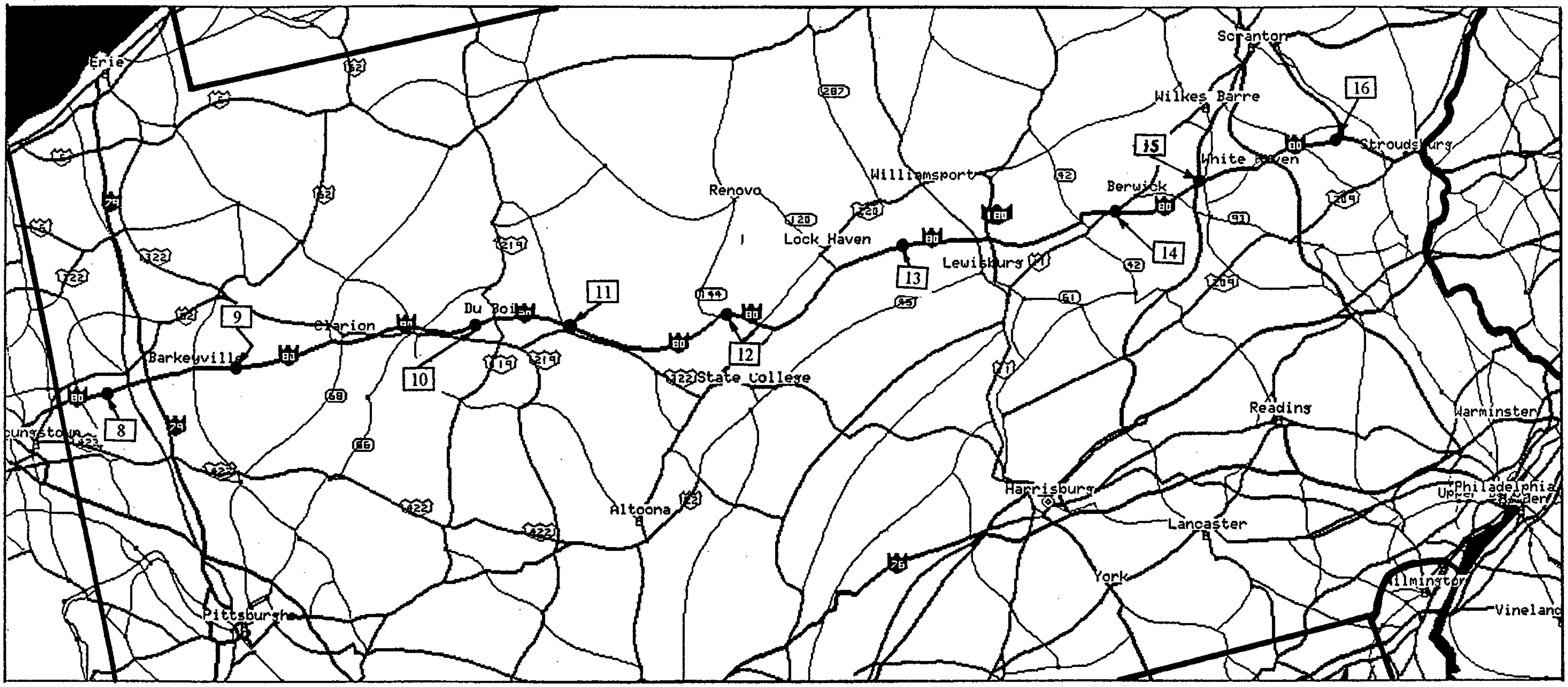
- The SCAN system is cost effective and reliable enough for the Department to recommend approval of this system for other Engineering Districts to utilize on future projects. The reliability issues will be addressed by requiring full extended warranties on all future projects.



District 1-0 Pavement Sensors

Ref #	Location	Installation Date
1.	**Venango Co. I-80 Mile Post 37.5**	**12/89**
2.	Crawford Co. S.R. 285 Pymatuning Reservoir Causeway	Fall/92
3.	Erie Co. I-79 at S.R. 6N Intersection	Fall/92
4.	Erie Co. I-79 Conrail Bridge	Fall/92
5.	Venango Co. S.R. 27 Fieldmore Hill	Fall/92
6.	Warren Co. S.R. 59 at the Kinzua Dam	Summer/94
7.	Mercer Co. I-80 Mile Post 11	Summer/94

Figure 6 - Location Map
(District 1-0 Sites)



Site Locations
(I-80 Corridor Study)

8. Mile Post 11 (Mercer County)
9. Mile Post 37.5 (Venango County)
10. Mile Post 90 (Jefferson County)
11. Mile Post 111.5 (Clearfield County)
12. Mile Post 146 (Centre County)
13. Mile Post 194.5 (Clinton/Union County)
14. Mile Post 246 (Columbia County)
15. Mile Post 259.5 (Luzerne County)
16. Mile Post 292 (Monroe County)

Figure 7 - Location Map
(I-80 Corridor Study Sites)

APPENDIX A

MANUFACTURER'S ROADWAY SYSTEM INSTALLATION MANUAL

Roadway System Installation Manual

Rev 1.11, 2/1/91

TABLE OF CONTENTS

TABLE OF DIAGRAMS

Introduction

You should have an SSI approved plan before beginning installation. The plan should include equipment locations and installation details regarding Surface Sensors, atmospheric sensors, the RPU/tower, the CPU/cabinet and other system peripherals.

When the installation is finished, call the SSI Technical Sales Support Department at 800-325-7226 to review the pre-commissioning checklist and schedule a commissioning trip by SSI personnel. A trip can usually be made within 2 to 4 weeks.

Failure to install equipment correctly may result in SSI technical personnel rejecting the installation; requiring corrections and a return trip to be made at the customer's expense.

REMOTE PROCESSING UNIT AND ALL SENSORS

Remote Processor Unit Site Selection

These guidelines should be followed when selecting the site for the RPU.

1. The cable length to any surface sensor or subsurface probe connected to the RPU must be less than 2500 feet.
2. There should be no buildings, structures, or trees nearby which would influence wind speed or wind direction measurements.
3. The RPU should be located on the same or higher level, and at least 100' from the nearest roadway. If the RPU cannot be located that far away from the roadway, a taller tower should be used to avoid truck spray from causing false readings on the precipitation sensor. If the tower is closer than 100' from the nearest roadway, the precipitation sensor must be located at least 30' high to avoid the spray.
4. Do not locate the tower where snow from plows or snow blowers will strike it.
5. Consider the proximity of electricity and telephone service needed by the RPU.
6. Locations where underground utilities (gas and water mains) might interfere with trenching or excavating the foundation should be avoided.

Pouring Tower Foundation/Service Pad

Your agency may have purchased SSI's "Complete Tower Package" to mount the RPU and its sensors. This package is complete with all the tower pieces and hardware to completely erect an RPU with all of its atmospheric sensors.

If this package was not purchased, the RPU and atmospheric sensors should be installed using these as guidelines rather than assembly instructions. If any questions arise please call the SSI Technical Sales Support Department 800-325-7226.

The tower SSI requires is a freestanding aluminum type, assembled with stainless steel hardware. This tower will withstand the high salt environment typically found near a roadway. As an added precaution against vandalism, a 6 foot cyclone fence with a gate entry, may be erected around the RPU tower.

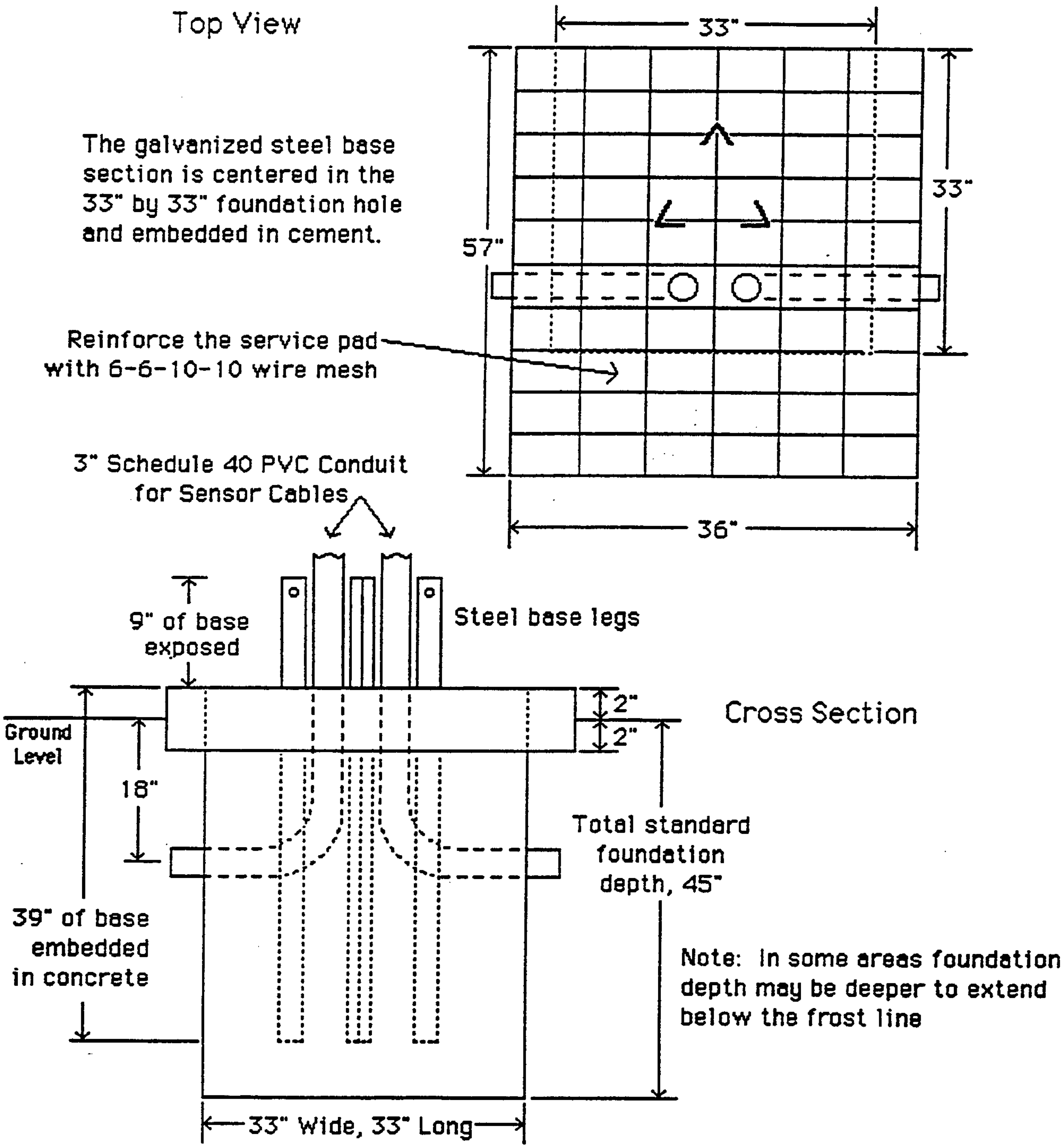
See "Tower Base Construction, Diagram 1" and "First Tower Section, Diagram 2."

See Tower Installation Procedure, Appendix A.

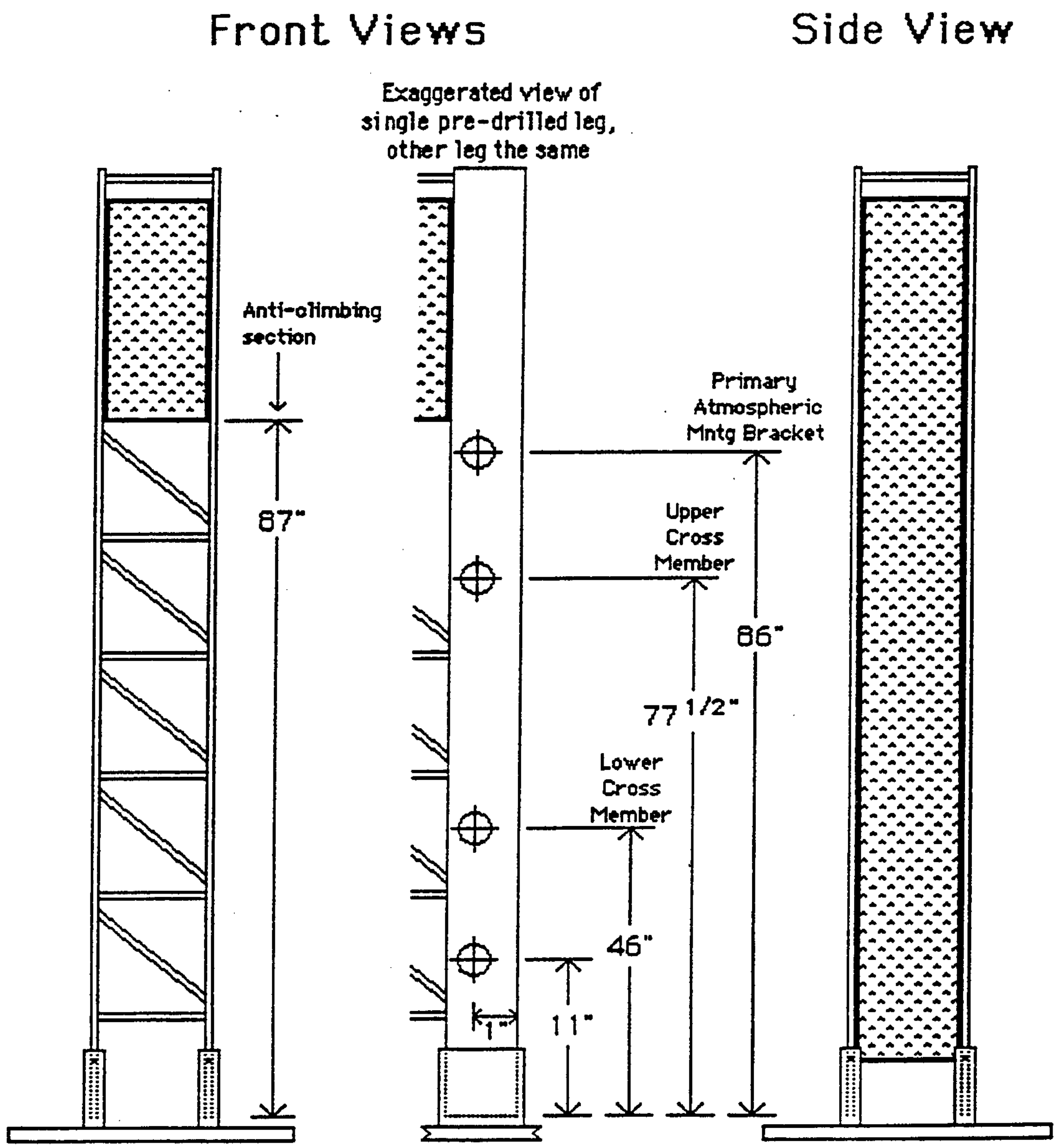
1. For any SSI supplied tower, excavate a hole for the minimum foundation dimensions 45" deep, 33" long, and 33" wide. When finished, the concrete foundation should extend 2" above ground level. A 36" diameter section of Sonotube may be used in pouring the foundation. In Northern areas the concrete foundation should extend below the frost line to insure a level installation for years to come. In sandy soils the concrete foundation should be larger. Note that two 3" PVC conduits for sensor cables are embedded in the foundation.

2. The service pad, which can be poured at the same time as the foundation, should be constructed adjacent and level to the main foundation. This pad should be 4" thick, 36" wide, 57" long and extend outward on the cabinet (open) side of the tower. Use a steel mesh, commonly called 6-6-10-10, to reinforce this pad.

Tower Base Construction
Diagram 1



First Tower Section
Diagram 2



All holes are pre-drilled, 13/32" ID for 3/8" hardware

Not to Scale

Note: For any tower in the Northern Hemisphere having photovoltaic arrays or solar panels mounted to it, the tower base should be poured with the open side facing South. That is, the service pad should be located on the South side of the base. Tower locations with sun shadowing of panels by trees or buildings (especially in the winter months) should be avoided. Instructions for mounting the solar system are provided separately and should be reviewed for specific recommendations and procedures.

3. The first 10' tower section has smooth non-climbable sides. Assemble the tower base section, with stainless steel hardware, to the first tower section so that the open portion is next to the service pad. Place the tower/base section into the center of the hole and position it so the open side faces the cabinet/service pad side of the foundation. The open side is for access to cables and hardware associated with the RPU cabinet.

4. Position two 3" Schedule 40 PVC conduits in the foundation hole as shown in "RPU Overview, Diagram 4." These conduits will be used to run the sensor cables into the RPU cabinet. Place the conduits so they open 18" below ground level.

5. Use staked off ropes as temporary guy wires to support the tower, as it must be kept standing straight and level. Pour the foundation hole and service pad base with concrete. The tower base section legs should extend 9" above the final level of concrete. Crown the top of the foundation/service pad slightly to prevent water accumulation. Allow the concrete adequate curing time before removing ropes.

<u>Assembling the Tower</u>

This step is not necessary for single section 10' towers, but applies to towers 20 or 30 feet tall, made up of 2 or 3, 10' sections. RPU tower height will vary depending on location parameters.

See Martin Tower Assembly Instructions, Appendix A.

1. Once concrete is fully cured, remove the ropes and the first tower section from the base.

2. If atmospheric sensors are included, install the mast on the top tower section with the hardware supplied.

3. Assemble the complete tower, laying on its side, on the ground.

4. Stand the completed tower upright and bolt it to the base with the 3/8" stainless hardware. A crane may be used to raise the tower but it may be done by hand since each section weighs about 30 lbs each.

Mounting the RPU Enclosure to the Tower

See "First Tower Section, Diagram 2," "Mounting the RPU Enclosure, Diagram 3" and "RPU Overview Diagram 4."

1. Using 3/8" x 1" stainless steel hardware, locate and mount the two 2' long pre-drilled aluminum cross members to the front tower face. The tower holes are pre-drilled at 46" and 77 1/2" above the fixed base.
2. Locate and mount the RPU enclosure to the pre-drilled cross members with 3/8" x 1 1/2" stainless steel hardware so the hinges are on the left.

Assembling and Mounting the RPU Radio Antenna

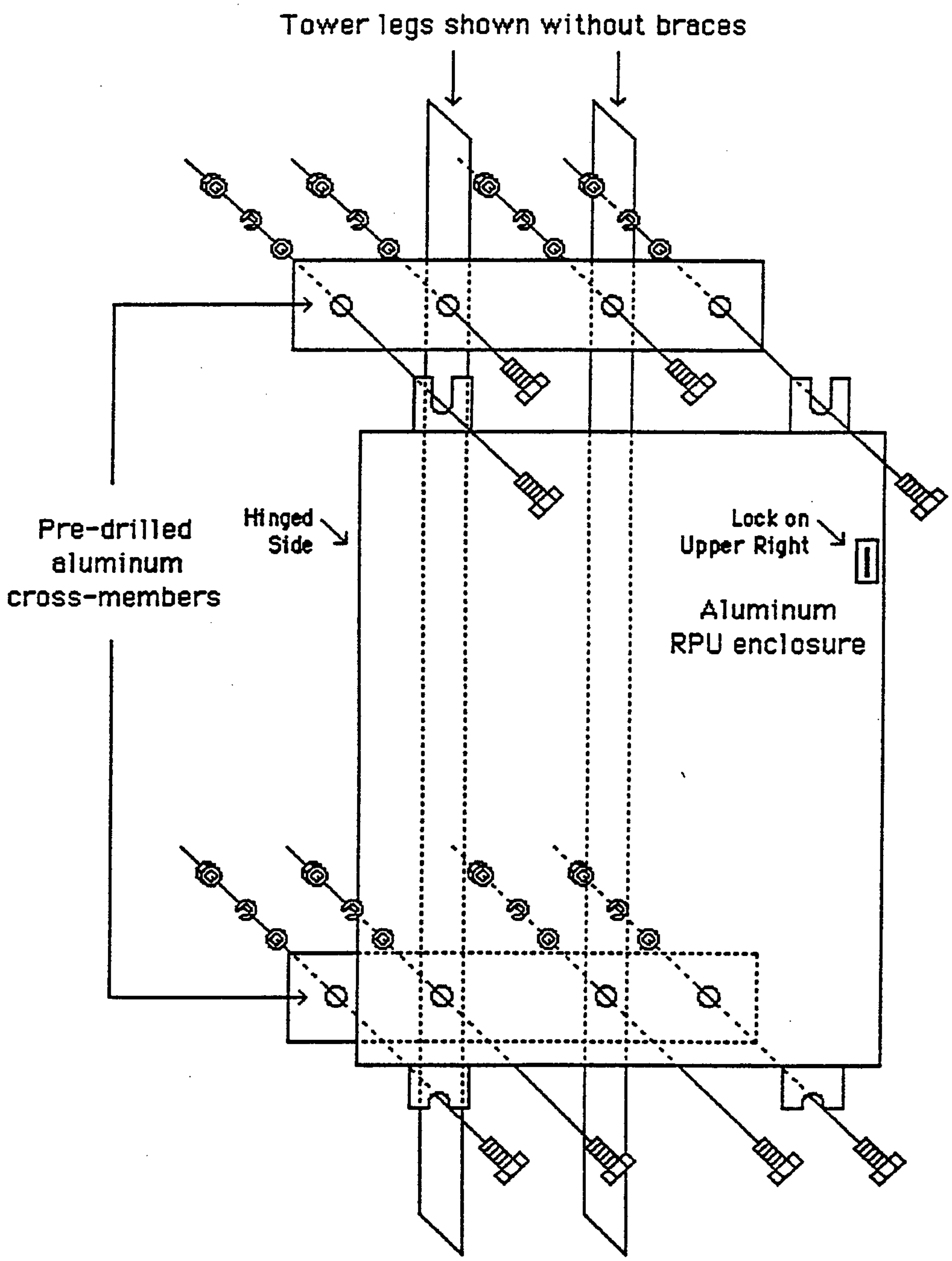
If the RPU does not have a radio antenna, disregard this section. In instances where the antenna is not mounted to the tower, but to something away from the RPU, the maximum coaxial cable run is 100'.

See "RPU Overview, Diagram 4" and "Radio Antenna Mounting, Diagram 5."

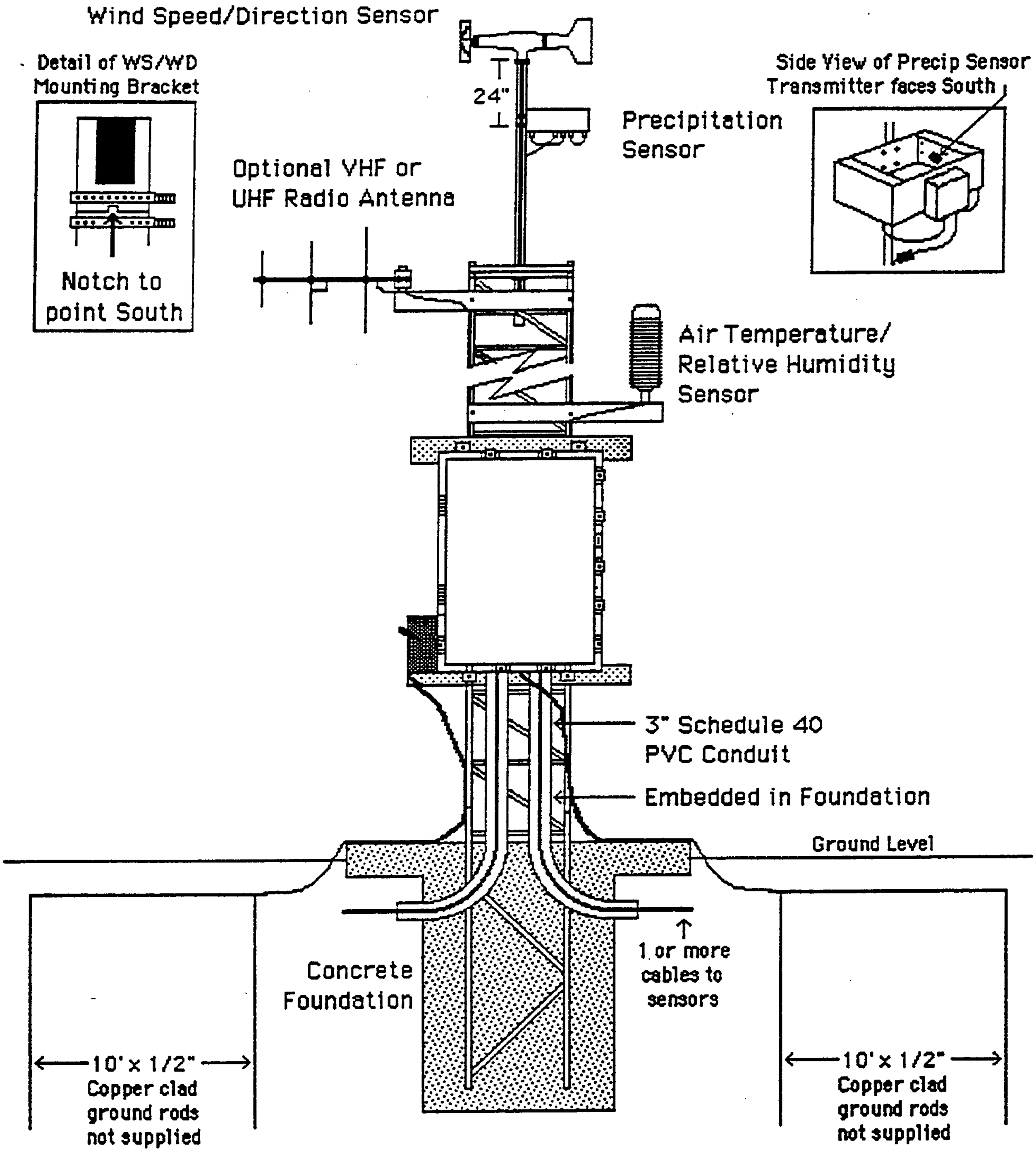
See ASP-816 Yagi Antenna Assembly, Appendix B.

1. Locate and assemble the radio antenna according to its packaged instructions. In most cases it will be the ASP-816 Yagi with pre-cut elements. The radio antenna type and mounting height are determined by the system FCC radio license. On 20 and 30 foot towers, this should be 20 foot above ground level. Please contact the SSI Technical Sales Support Department if you are in doubt.
2. Locate the pre-drilled aluminum antenna mounting bracket. At the correct antenna height, drill one 13/32" hole on each leg of the tower using the bracket as a template to mark the 2 hole locations. Mount the bracket to the tower with 3/8" x 1" stainless steel hardware.
3. Mount the antenna to the bracket tube with the U-bolts and universal mounting plate. Make sure to point the gamma matcher down (opposite of what the ASP-816 Yagi Antenna Assembly Instructions say) and position the antenna elements vertically. Be sure the antenna is pointing towards the CPU antenna location before tightening the hardware.

Mounting RPU Enclosure
Diagram 3



RPU Overview
Diagram 4



Installing the RPU Radio Cable Feed-through Connector

See "RPU Radio Cable Feed-through Connector, Diagram 6."

1. Drill a 5/8" through hole in the bottom right hand side of the RPU cabinet. The feed-through connector, shipped attached to one end of the antenna coaxial cable, fits in this hole. Install it half in and half out of the cabinet, tightening nuts as shown.

Wiring RPU Radio Antenna

Refer to "Radio Antenna Mounting, Diagram 5" and "RPU Radio Cable Feed-through Connector, Diagram 6."

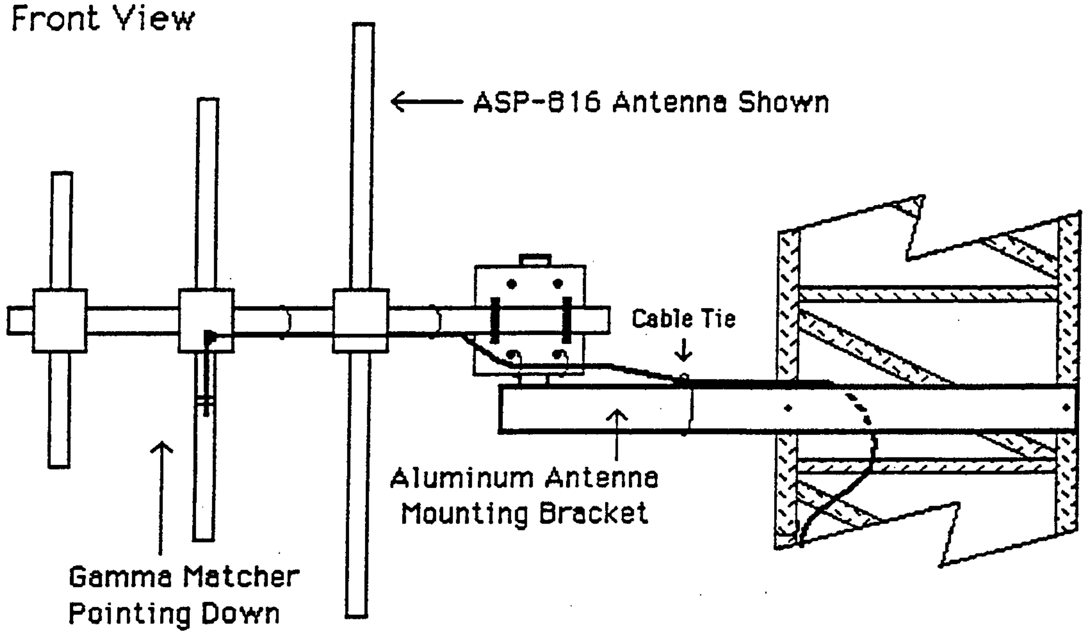
1. Plug one end of the antenna coaxial cable to the threaded PL-259 adapter on the antenna gamma matcher. Run the cable along the antenna beam and across the mounting plate. Secure the cable to the mounting plate with two cable ties running through the holes in the lower part of the plate.

2. Run the cable along the top edge of the Antenna Mounting Bracket and secure with cable ties. Make a gentle bend in the cable and run it down inside one of the tower's legs to the underside of the RPU cabinet, securing every 18" with weatherproof cable ties. Do not run any other cables down the same leg as the antenna coaxial cable.

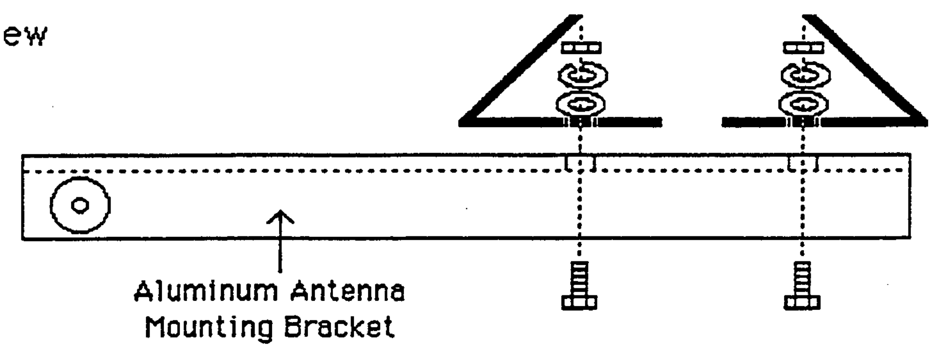
3. Connect the other end of this cable to the threaded feed-through connector on the underside of the RPU. Spool up and tie wrap any excess cable.

Radio Antenna Mounting
Diagram 5

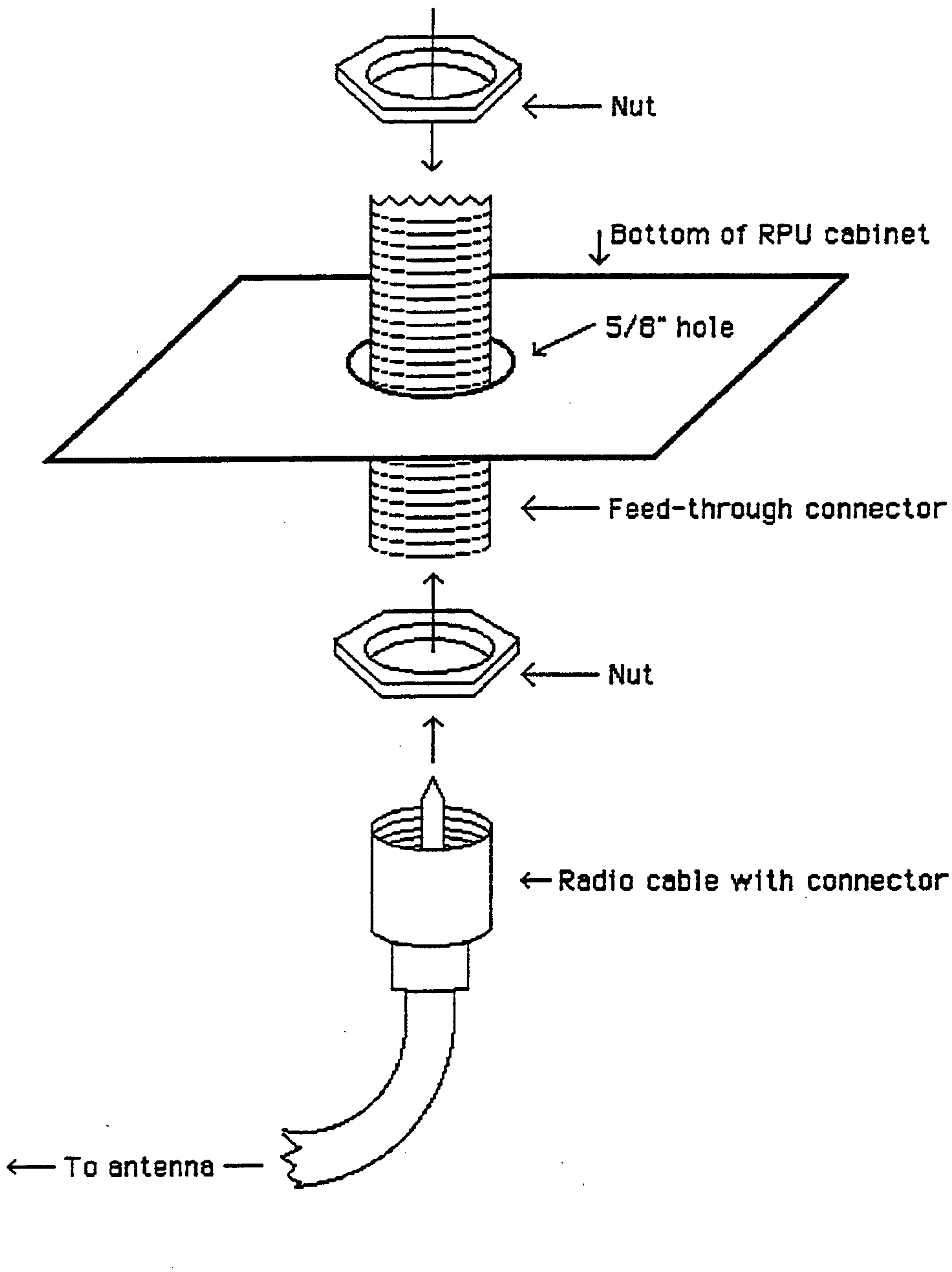
Front View



Top View



RPU Radio Cable Feed-through Connector
Diagram 6



Atmospheric Sensor's Mounting Facts

Atmospheric sensors include; wind speed/direction, relative humidity/air temperature and precipitation. If atmospheric sensors are located away from the RPU, the maximum cable distance between sensors and the RPU is 150'. Atmospheric sensor cables are 50' unless otherwise specified, and are weatherproof, but are not suitable for direct burial in the ground. Other ways of mounting the atmospheric sensors should be approved by the SSI Technical Sales Support Department.

1. If the RPU is further than 100' from all roadways and there are no hills or obstructions nearby, only a 10' tower is required.

2. If the RPU is closer than 100' to any roadway, a 20' or 30' tower will be required as the precipitation sensor must be mounted 30' above the highest roadway surface to avoid road spray giving the sensor a false reading.

3. Under no circumstances is the tower to be mounted where the sensors will be hit by snow from a plow or snow blower.

Mounting Atmospheric Sensors

RPUs vary in their use of atmospheric sensors and some sensors may not be included. The following directions are for mounting all of the atmospheric sensors, if some are not included disregard the steps describing their mounting.

See "RPU Overview, Diagram 4," and "Relative Humidity/Air Temperature Sensor Mounting, Diagram 7", and "Wind Speed/Direction Sensor Mounting, Diagram 8."

1. Bolt the pre-drilled Relative Humidity/Air Temperature Sensor Mounting Bracket, using 3/8" x 1" stainless steel hardware, to the 2 pre-drilled holes on the front tower legs. These holes are 86" above the fixed base section. Mount the Relative Humidity/Air Temperature Sensor on the end of the sensor bracket using the bolt provided in the sensor base. Secure the cable along the bracket with weatherproof cable ties.

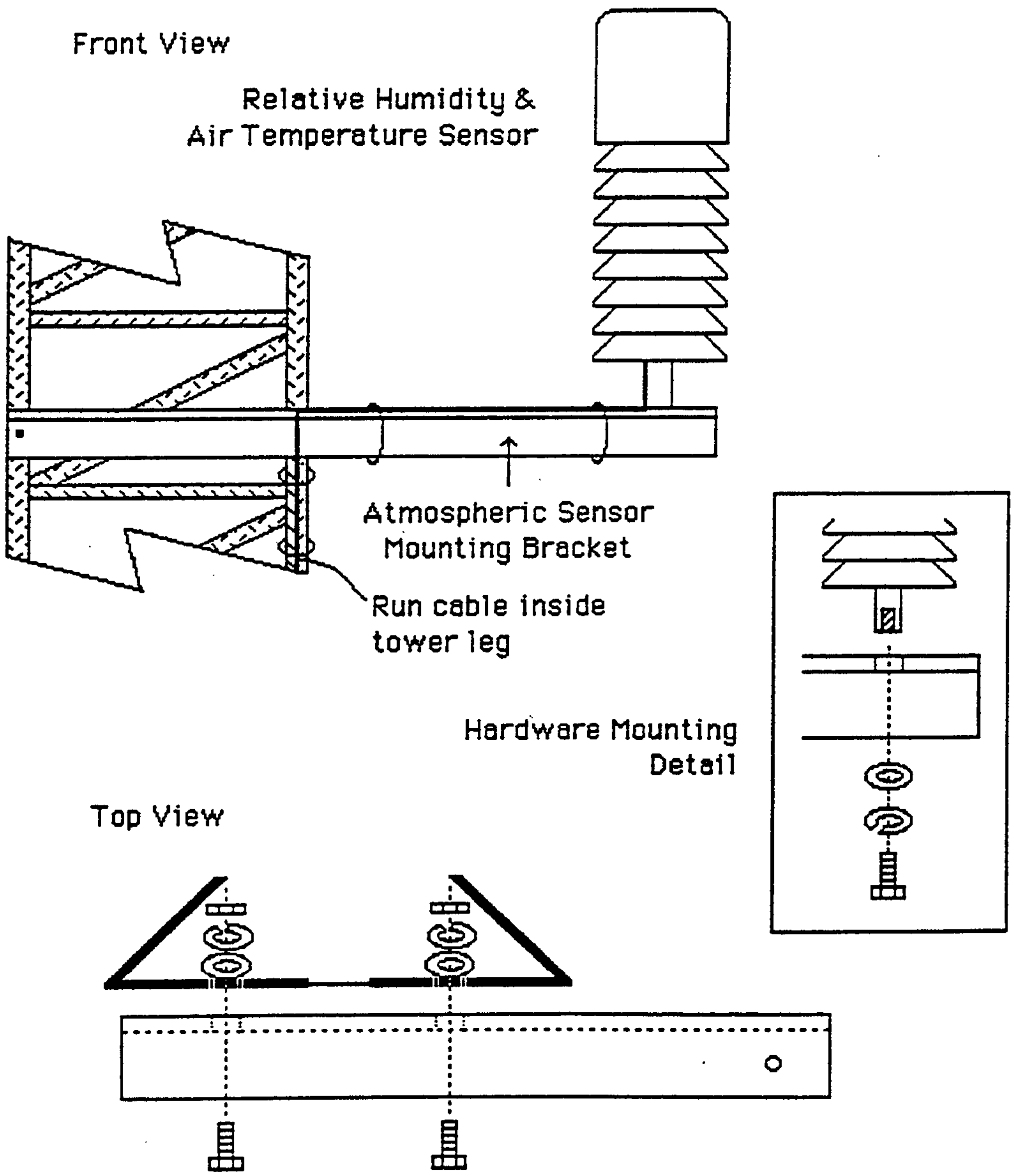
2. The Wind Speed/Direction Sensor mounts on top of the 1" mast supplied with the tower. An orientation ring is provided so the instrument can be removed for maintenance and reinstalled without loss of wind direction reference. Orient the base so the junction box faces due South. Make sure the orientation ring indexing pin is in the notch at the instrument base. Tighten the mounting post and orientation ring band clamps.

3. The Rudolph precipitation sensor is mounted 24" below the top of the mast. Orient the frame so the four "eyes" of the sensor are looking south. Secure the sensor with the two U-clamps provided. CAUTION: Do not over tighten these clamps or the sensor frame will be deformed.

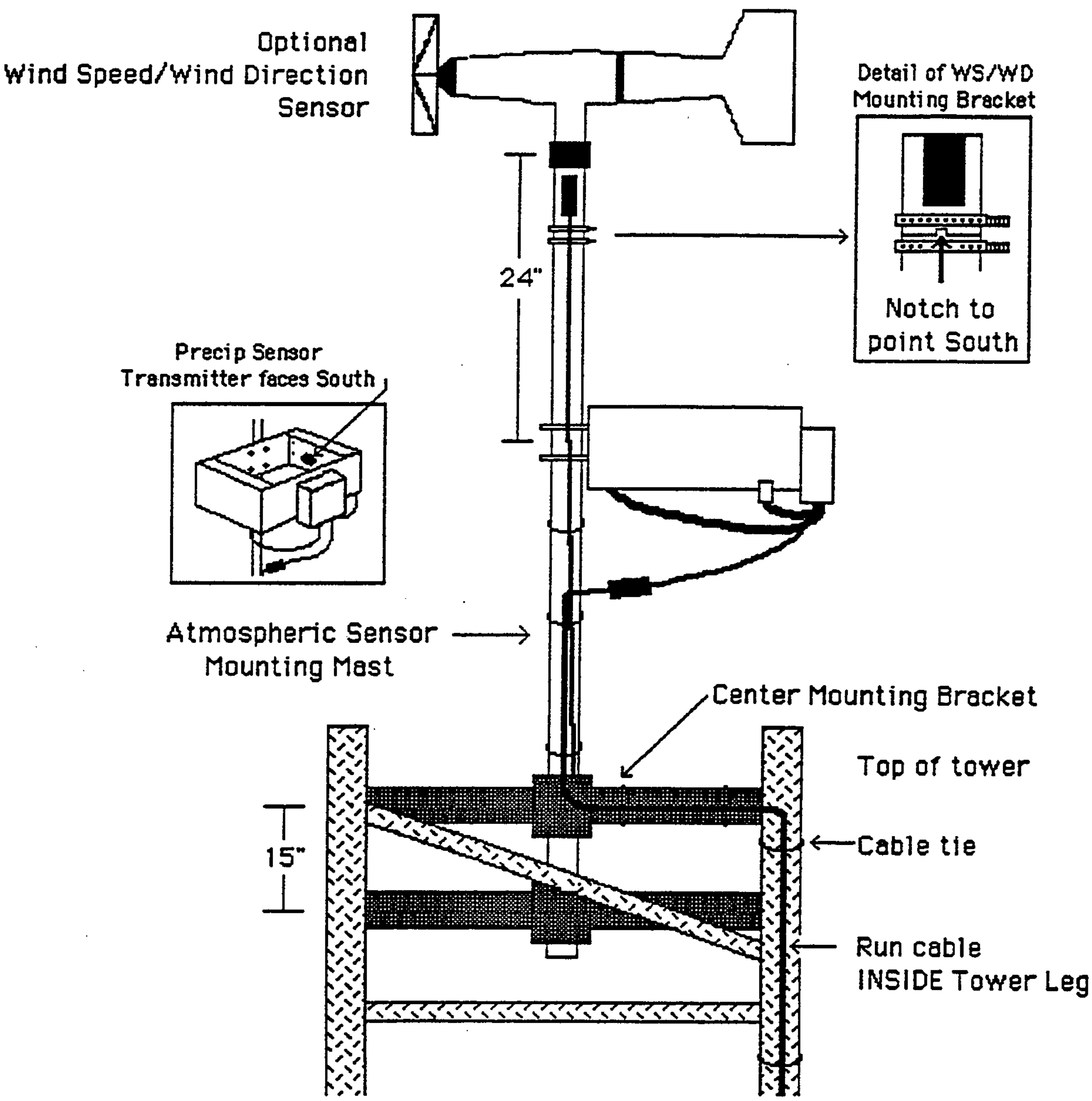
4. Run all the sensor cables together down the mast and then inside the closest tower leg and finally to the underside of the RPU cabinet. Secure them every 18" with weatherproof cable ties.

5. In the bottom of the RPU cabinet drill one hole for each sensor cable. Install an appropriate rubber bushing connector (not supplied by SSI) for each of the atmospheric sensor cables. Leave 20' of cable from each sensor spooled inside the RPU cabinet. Tag each cable with its sensor identification.

Relative Humidity/Air Temperature Sensor Mounting
Diagram 7



Wind Speed/Direction Sensor Mounting
Precipitation Sensor Mounting
Diagram 8



Grounding the RPU

The tower and RPU must be grounded for safety, lightning protection, and signal integrity reasons. If a standard SSI tower package is supplied, follow the following procedure:

See "Ground Rods and Cables, Diagram 9", "Tower Grounding, Diagram 10" and "RPU Overview, Diagram 4."

1. Cut two 12' lengths and one 17' length from the 32 strand, #210 weight, 7/16" diameter tinned copper cable supplied. Save the remaining cable for use in a later step. Locate 3 of the 5 aluminum lug connectors. NOTE: The remaining two lugs will be used in step 4. Locate the pre-drilled 13/32" holes just above the tower base on each aluminum tower leg. Secure the three lugs to the tower legs with 3/8" hardware. Attach the ends of the two shorter cables to the lug connector and tighten the set screw securely with a hex wrench. Run 5' of the longer third cable through the third lug connector and tighten the set screw securely. The end of this longer cable will be connected to the bottom of the RPU cabinet later. Fasten the cable to the surface of the concrete pad with suitable clamps and anchors, not supplied by SSI. Place the clamps at least every 18" so they hold the cable flat against the pad surface so as to avoid presenting a trip hazard.

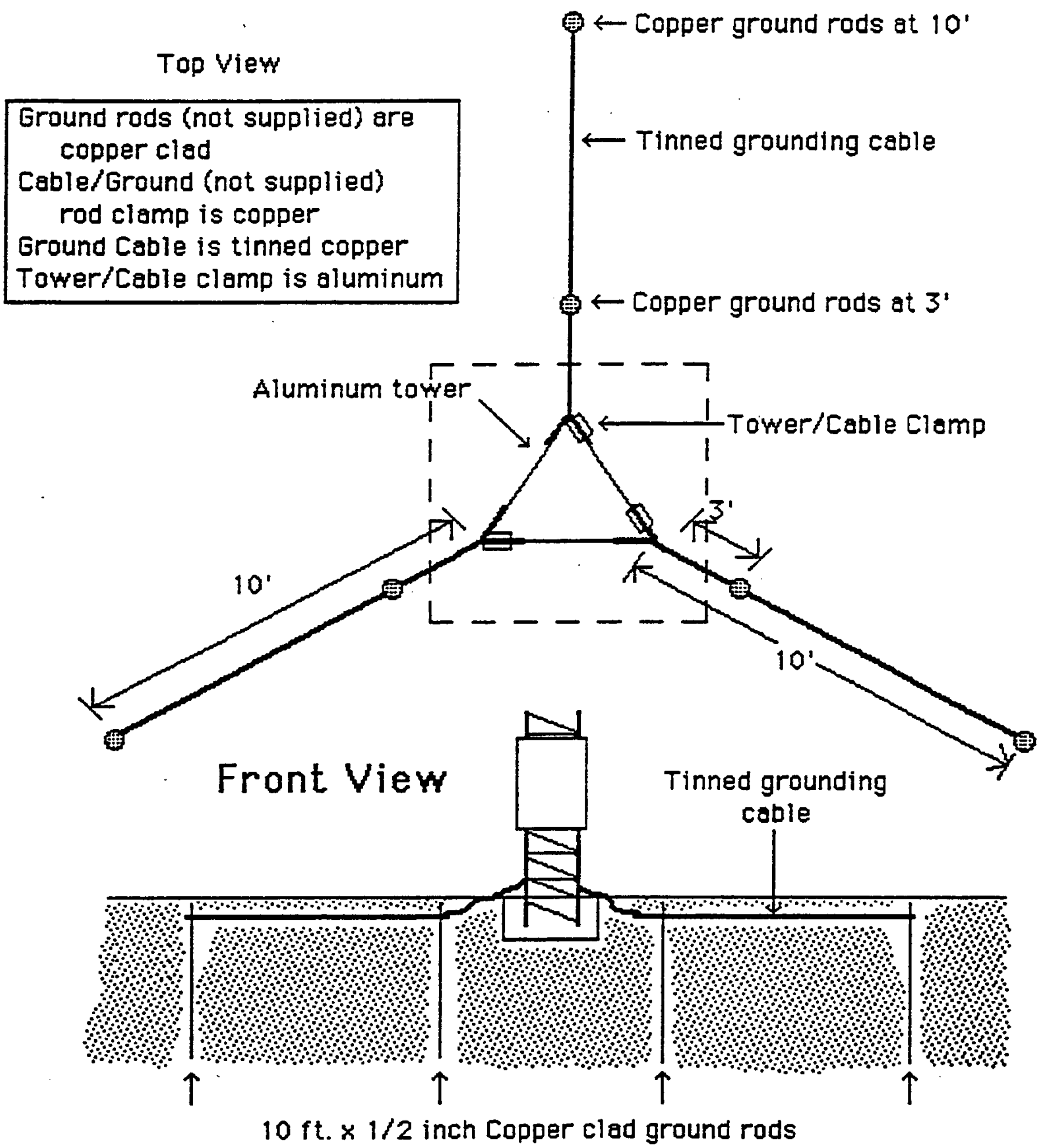
2. Bury the 3 cables equidistant from each other, 1' below grade and straight out from each leg. Along each cable, 3' and 10' out from the each tower leg, sink a 10' long x 1/2" copper clad grounding rod, 6 total, not supplied by SSI.

3. Attach the cables to the ground rods with appropriate copper clamps, 6 total, not supplied by SSI. Finish sinking each ground rod so that their tops are 2" below grade.

4. Drill a 13/32" hole in the center of the RPU cabinet bottom. Locate the two remaining aluminum lug connectors. Using one 3/8" bolt, fasten one lug inside and one outside the RPU cabinet. Secure the free end of the 17' ground cable to the lug outside the cabinet. This cable should be run up the tower leg, securing it every 18" with weatherproof cable ties. An internal grounding cable will be attached to the inside lug later.

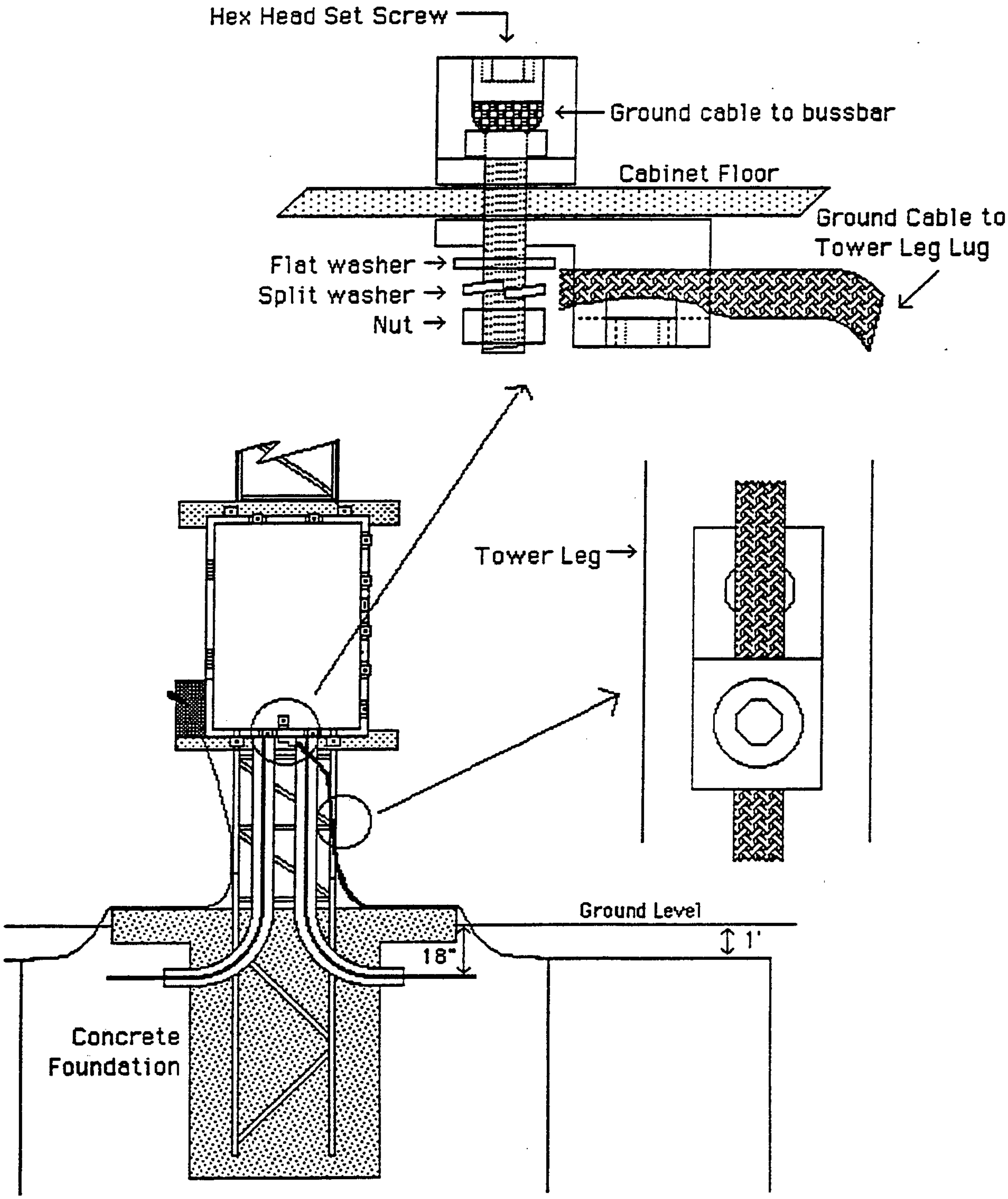
Although the vast majority of roadway RPUs are mounted on the standard SSI supplied tower package, there are a small number that are not. These include RPUs placed inside structures, mounted on pillars, or attached to bridges. It is beyond the scope of this manual to attempt to cover all possible grounding situations. Contact SSI Technical Sales Support to develop a grounding method for each RPU not mounted on a SSI supplied tower.

Ground Rods and Cables
Diagram 9



Not to Scale

Tower Grounding
Diagram 10



Installing the Surface Sensor and Subsurface Temperature Probe

The following steps make up a general description of a typical Surface Sensor installation. They should be used as guidelines to fit any RPU and sensor roadway configuration.

Detailed instructions for installation of both the Surface Sensor and the optional Subsurface Temperature Probe into a roadway or bridge deck are contained in a separate manual entitled "Surface Sensor and Subsurface Probe Installation Manual."

Detailed instructions to splice Type V extension cable to Type IIA sensor cable are contained in a separate manual entitled "Type V Sensor Cable Splicing Instructions."

See "Surface Sensor Installation Overview, Diagram 11," "Surface Sensor in Bridge Deck, Diagram 12" and "Surface Sensor in Roadway, Diagram 13."

See Type V Cable Specifications, Appendix C.

1. All Surface Sensors and Subsurface Temperature Probes come with 150' of non-removable Type IIA sensor cable molded into each sensor. This Type IIA weatherproof sensor cable is installed directly in pavement sawcuts with a low temperature (under 200° F) filler or inside conduit. DO NOT install Type IIA cable in EXPANSION JOINTS or DIRECTLY BURIED IN THE GROUND WITHOUT CONDUIT PROTECTION. Although Type V cable may be directly buried without conduit protection, do not install it in expansion joints either.

   Example: In a bridge deck installation, the Type IIA sensor cables must be inside conduit attached to the underside of the bridge, back to a junction box.

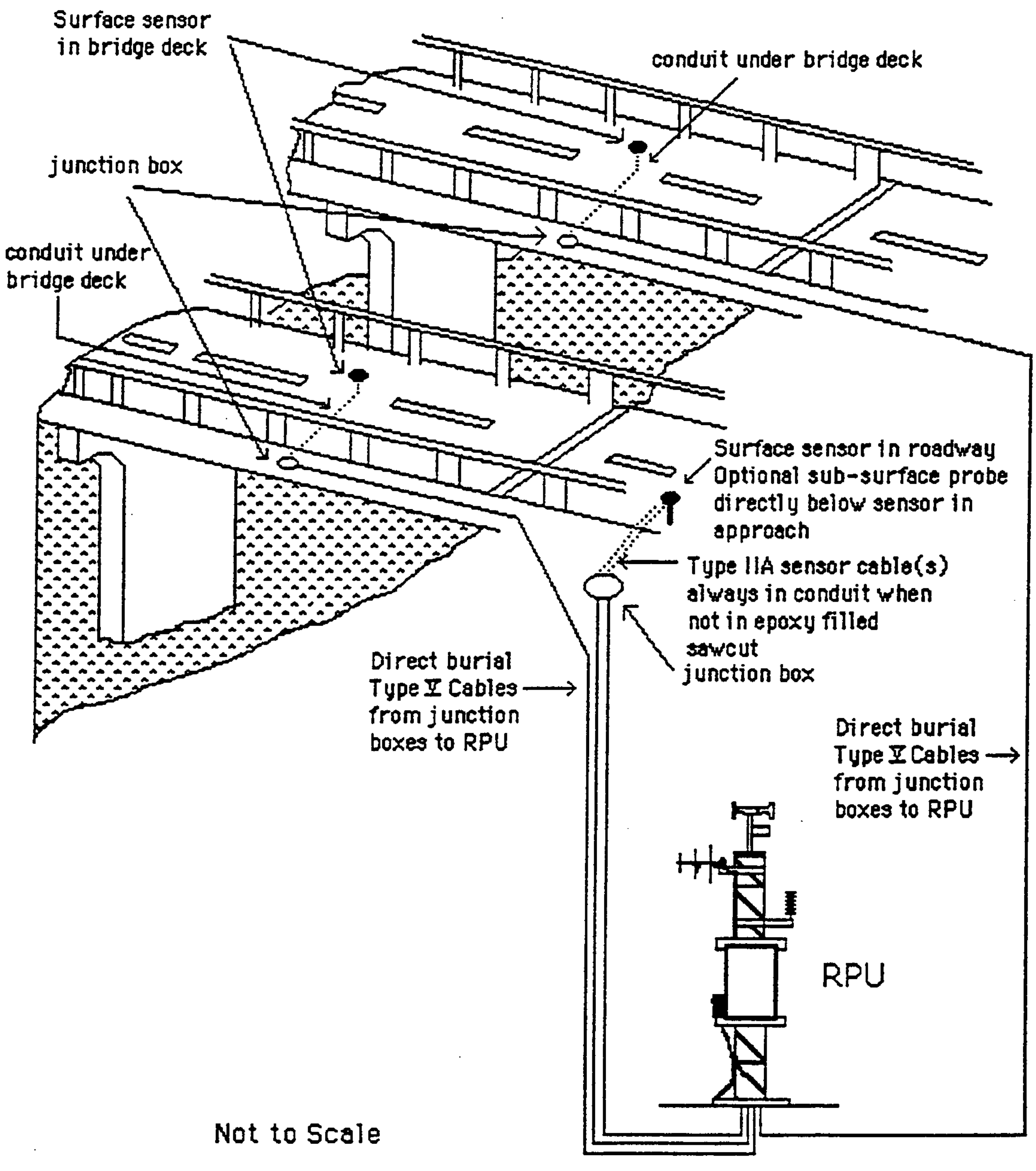
2. Install corrosion resistant junction boxes or splicecans (not supplied by SSI) in an easily accessible location near the edge of the roadway. The minimum size of each box is 18" x 18" x 4", adding an extra 2" in depth for each additional splice. Conduit, used to protect sensor cable between the roadway edge and the splicecan, is to extend 2" into the edge of the pavement.

3. Install the sections of Type IIA cable and the 14 gauge stranded copper external ground wires (not supplied by SSI) to each junction box. Coil up the left over Type IIA cable inside the boxes, waterproofing each end. Ground each junction box and ground wire to a 1/2" x 10' copper clad ground rod (not supplied by SSI) or to part of the grounded metal bridge structure. In a few instances the Type IIA sensor cable will reach the RPU. In this case connect the ground wire to one of the existing RPU ground rods. The Subsurface Temperature Probe requires no external ground wire.

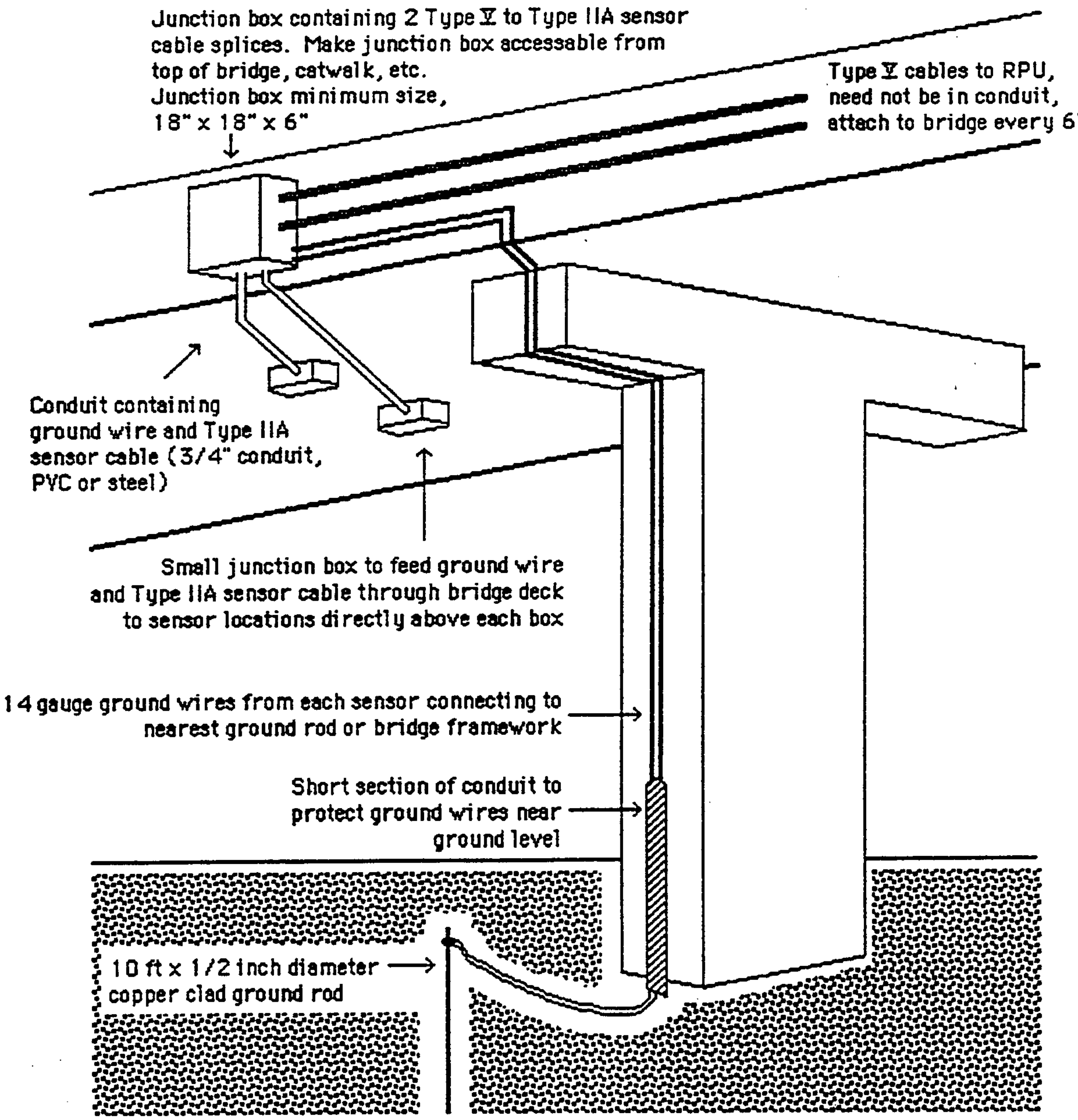
4. Trench or install above ground in conduit, a separate Type V direct burial Surface Sensor extension cable for each sensor. This cable runs from the junction boxes to the RPU.

   Example: For 3 Surface Sensors and 1 Subsurface Temperature Probe, 4 separate runs of Type V cable are required.

Surface Sensor Installation Overview
Diagram 11

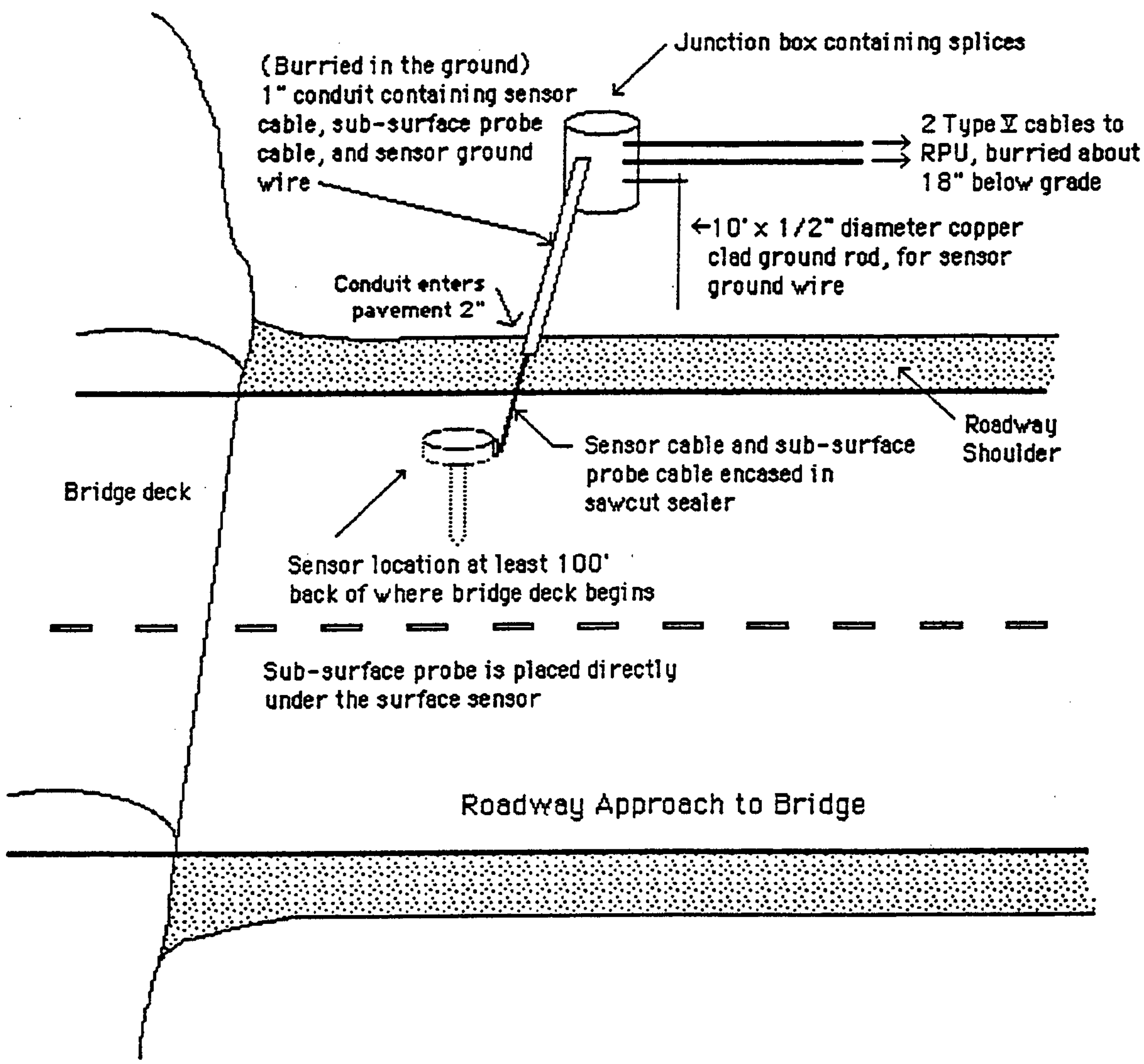


Surface Sensor in Bridge Deck
Diagram 12



Not to Scale

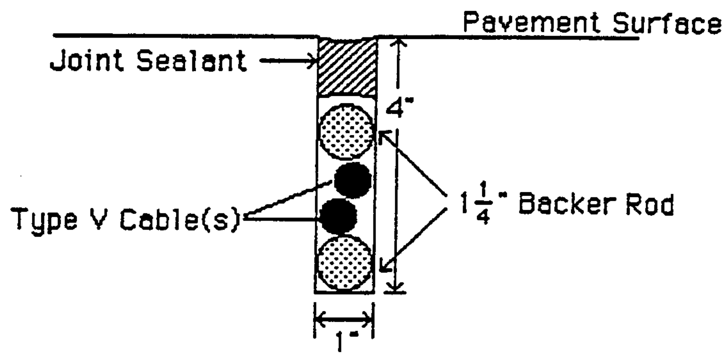
Surface Sensor in Roadway
Diagram 13



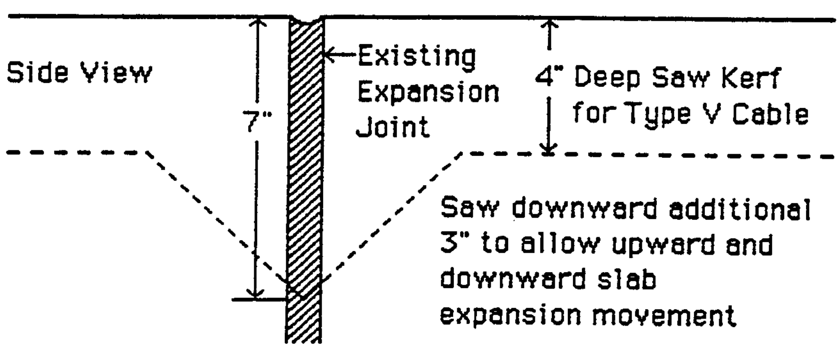
Not to Scale

Installing Type V Cable in a Saw Kerf
Diagram 14

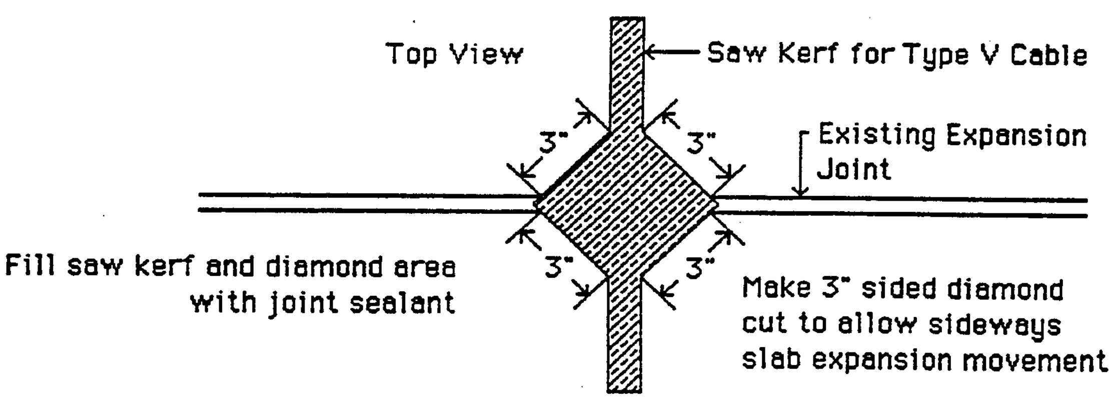
Saw Kerf Cross Section



Saw Kerf Crossing Expansion Joint



Saw Kerf Crossing Expansion Joint



5. The maximum total cable distance from each sensor head or probe to the RPU is 2500'. Type V direct burial cable should be installed according to local electrical code. Any cable installed above ground must be protected by conduit. DO NOT INSTALL Type V CABLE IN THE SAME TRENCH OR WITHIN 26" PARALLEL TO, ANY OTHER CABLE. Type V cables may be placed together in the same trench.

6. Once back at the RPU, the 2 sections of 3" PVC conduit (not supplied by SSI) should be used to feed up to 4 of these cables per conduit into the RPU cabinet. This conduit should open about 18" below grade. Leave about 6' of each Type V cable spooled inside the cabinet and mark each cable as to sensor location and serial number. A megohmeter should be used to check the Type V cable prior to splicing. NEVER USE A MEGOHMETER TO CHECK Type V CABLE ONCE IT HAS BEEN SPLICED TO THE SURFACE SENSOR TYPE IIA CABLE.

7. Splice the Type V to IIA cables at each junction box with Scotchcast 3M 8982/GEL splice kits according to the "Type V Sensor Cable Splicing Instruction Manual." Tag each splice with the sensor location and serial number. Loop several feet of excess cable inside the splice can so there will be sufficient cable available should the splice have to be replaced at a later date.

Assembling the RPU Backpanel

Before the RPU backpanel can be mounted inside the cabinet, the following sub-assembly is required.

See "RPU Backpanel Layout, Diagram 15" and "RPU Backpanel Hardware Detail, Diagrams 16, 17, and 18."

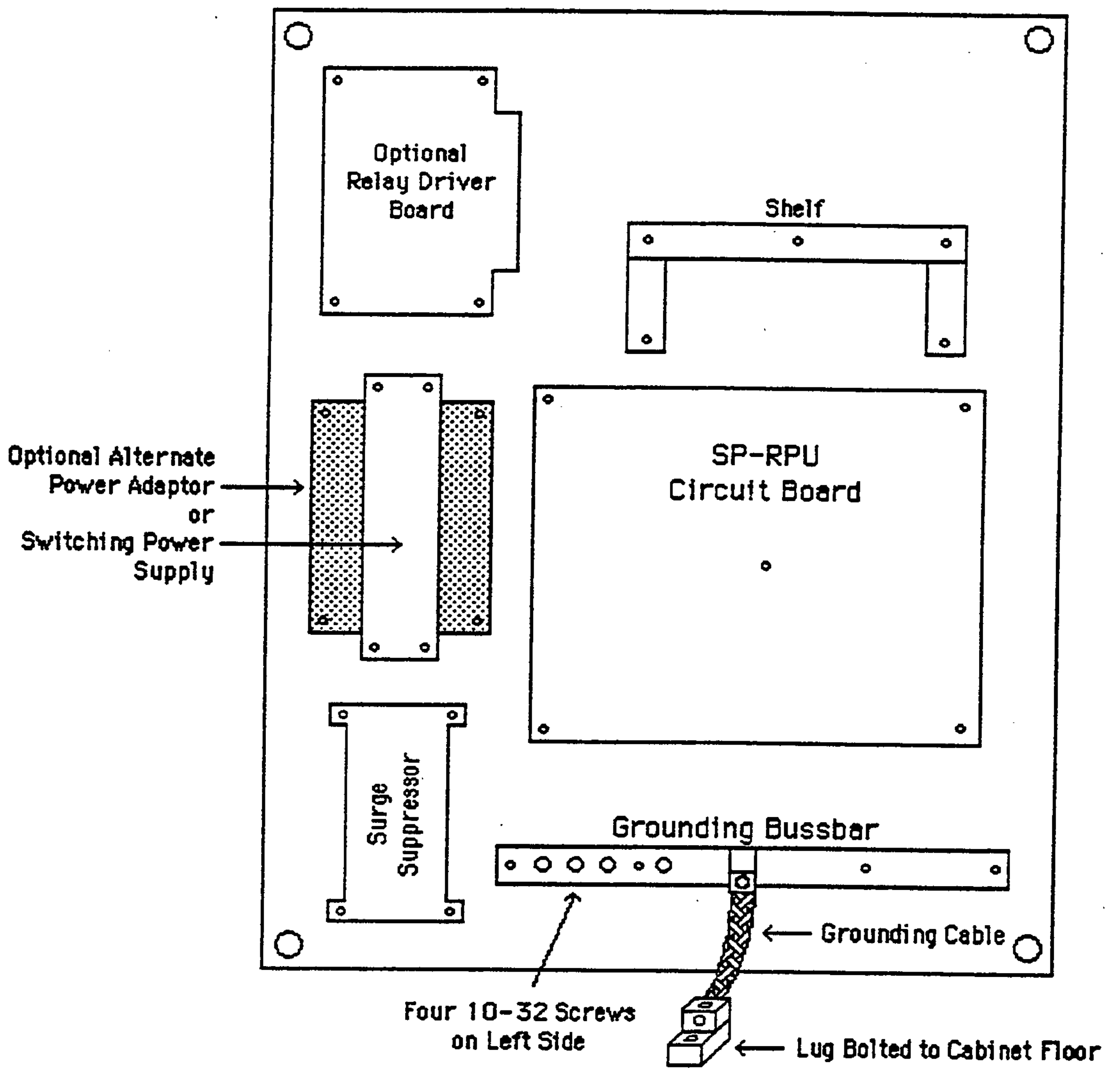
1. Locate the pre-drilled RPU backpanel. Taped to the back is the RPU circuit board mounting hardware. Set this #6-32 hardware aside for use in step 3. Locate the surge suppressor quad box. Mount the quad box to the backpanel in the lower left hand corner.

2. Locate the shelf and mounting hardware attached. Mount the shelf on the upper right hand side of the backpanel.

3. Hardware must be installed on the backpanel to hang the circuit board. Use the RPU Mounting Hardware from step 1 and mount this hardware securely. There should be five #6-32 nuts and nylon washers left over. Place them loosely on the standoffs so they will not be lost.

4. Locate the power supply. Mount the power supply on the left side of the backpanel with the 6-32 hardware supplied. The power supply should be mounted with the connectors toward the lower edge of the backpanel.

RPU Backpanel Layout
Diagram 15

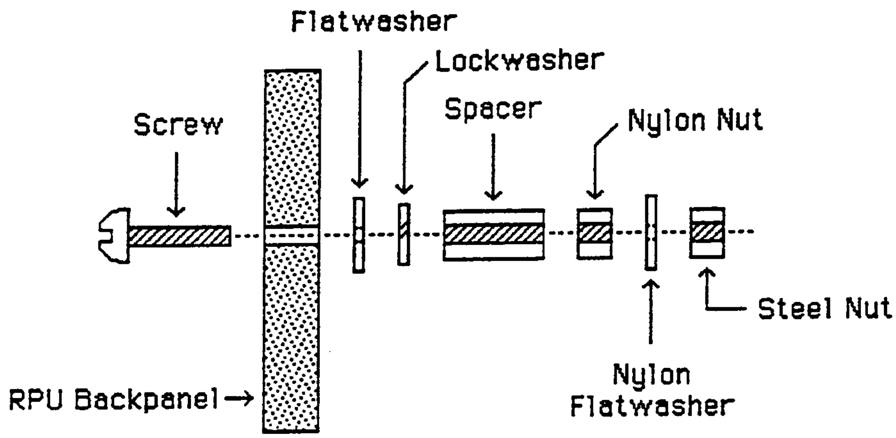


See hardware detail programs
to mount each individual assembly

RPU Backpanel Hardware Detail
Diagram 16

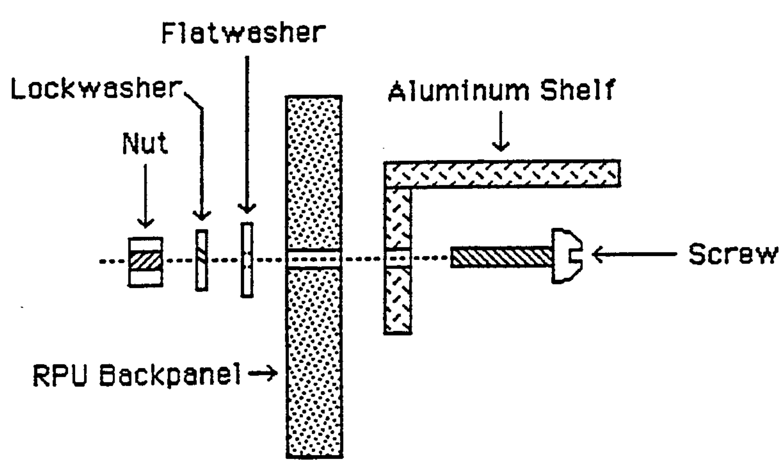
Installing the SP-RPU Circuit Board Mounting Hardware

Note: All hardware is 6-32 stainless steel unless otherwise stated



Mounting the Aluminum Shelf

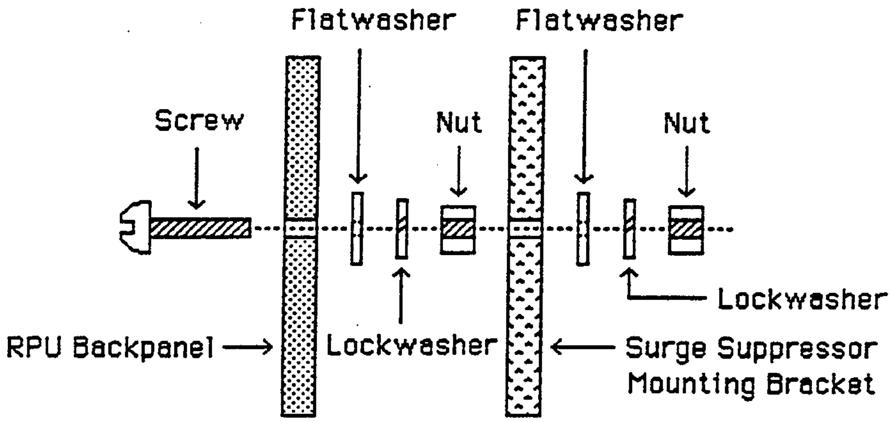
Note: All hardware is 6-32 stainless steel



RPU Backpanel Hardware Detail (Cont'd)
Diagram 17

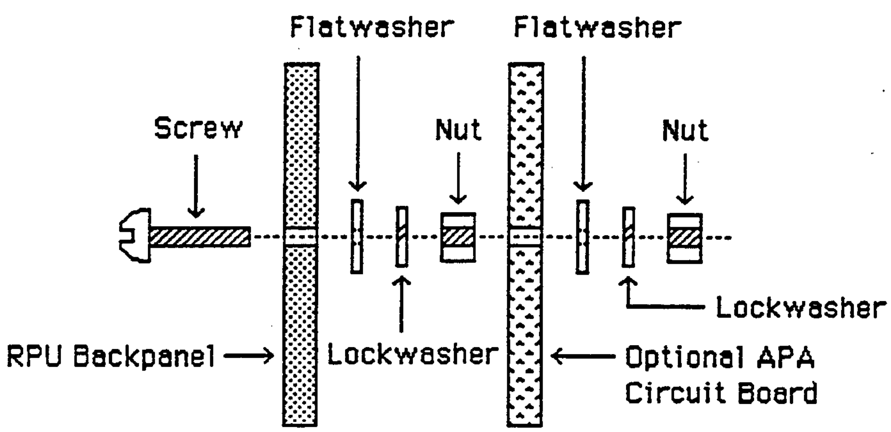
Mounting the Surge Suppressor

Note: All hardware is 6-32 stainless steel



Mounting the Optional
Alternate Power Adapter

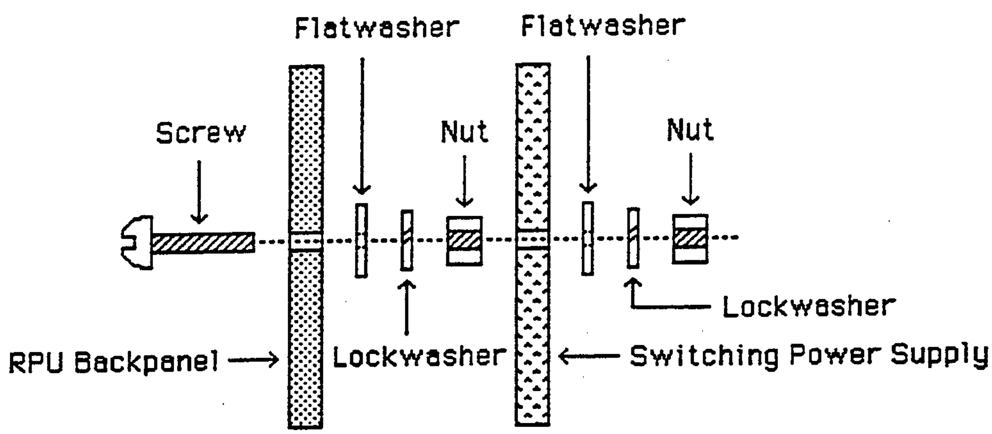
Note: All hardware is 6-32 stainless steel



RPU Backpanel Hardware Detail (Cont'd)
Diagram 18

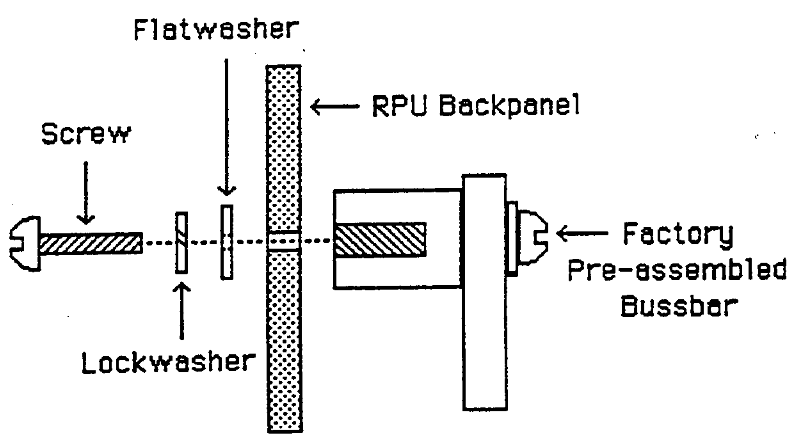
Mounting the Switching Power Supply

Note: All hardware is 8-32 stainless steel



Mounting the Grounding Bussbar

Note: All hardware is 10-32 stainless steel



5. Locate the RPU Grounding Bussbar and attached hardware. Fasten the Bussbar to the backpanel near the lower edge. The four larger bolts, which will be used later for connecting the sensor cable shields, are to be on the left side. When the bussbar is correctly installed, the large ground lug in the center of the bussbar will be toward the bottom of the cabinet.

6. Mount the backpanel inside the RPU cabinet with four 3/8" stainless steel bolts, pre-packaged inside the RPU cabinet. Tighten these bolts securely.

Installing the RPU Main Disconnect

See "Installing the RPU Main Disconnect, Diagram 19."

1. Mount an appropriate fused Nema 3R disconnect enclosure (not supplied by SSI) for a 15A, 120 VAC service, to the left outside wall of the RPU cabinet. Drill a hole through the RPU cabinet for interconnect wiring. Mount a duplex box on the left inside wall of the enclosure, immediately behind the disconnect

2. Install an appropriate lightning arrestor (not supplied by SSI) on or inside the disconnect. Use Romex or similar material (not supplied by SSI) to wire the disconnect to the duplex box. Wire the duplex box, lightning arrestor and disconnect together according to local electrical code.

3. Cut and run a piece of #14 AWG or larger grounding cable from the ground terminal inside the disconnect down one of the tower legs, to one of the previously installed ground cable lug connectors. Secure the cable with the connector and attach the cable to the tower leg every 18" using weatherproof cable ties.

Supplying Power to the RPU

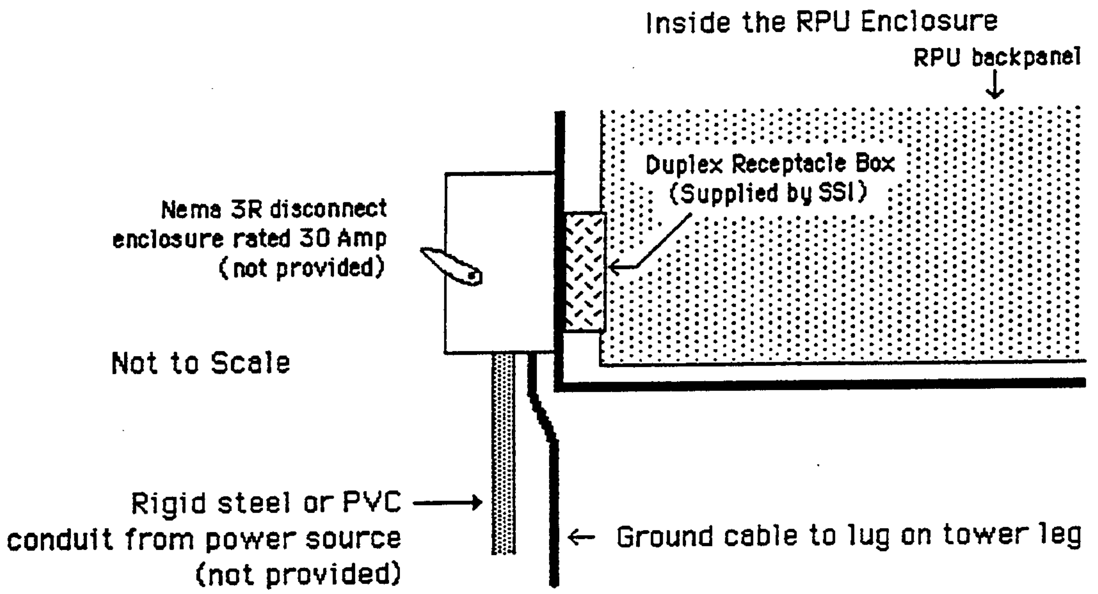
The non-solar RPU power requirement is a nominal 115 VAC, 50/60 Hz at 15 Amps.

1. The line regulation at the disconnect must be such that the voltage must not vary more than 5% from full load to no load condition.

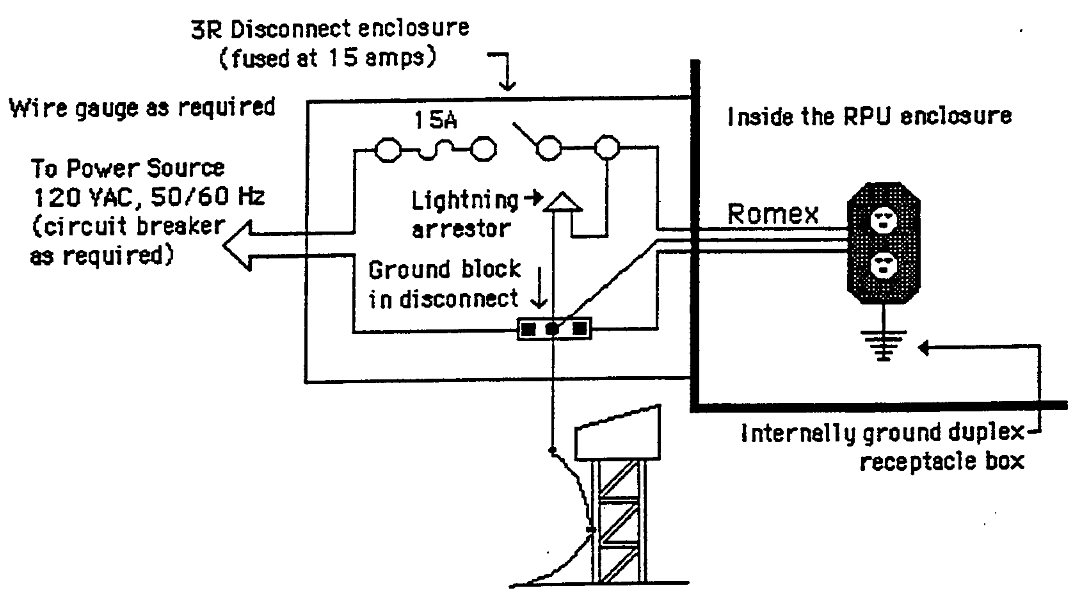
2. If a local power company is being contracted to supply power to an RPU, a meter may have to be set. From there the power should be run according to local electrical code into the RPU main disconnect.

3. Once power is supplied to the RPU disconnect, it should remain off until SSI technical personnel commission the system.

Installing the RPU Main Disconnect
Diagram 19



Schematic



Internal RPU Cabinet Final Assembly

This section describes the final assembly inside the RPU cabinet and what equipment should be left there. No wiring need be done inside the RPU cabinet except the duplex box wiring discussed previously.

Do not plug any equipment into the duplex box.

See "RPU Backpanel Layout, Diagram 15" and "RPU Backpanel Hardware Detail, Diagrams 16, 17 and 18."

1. The printed circuit board for the RPU should be left sealed in its' original shipping carton. The commissioning technician will install this board when the system is commissioned. Place the 5 nylon washers and metal nuts on the mounting stand-offs so they will not be lost.

2. If the RPU includes a radio, place the radio and power supply on the shelf and leave both power cables in the bottom of the cabinet.

3. If the RPU includes a Hayes modem and power interrupter (it will not have a radio or power supply), place them on the shelf and leave the power supply module cable in the bottom of the cabinet.

4. Cut a short length of grounding cable from the piece remaining from tower grounding. Run this cable through the ground lug on the bussbar and fasten it to the ground lug mounted to the bottom of the RPU cabinet. Securely tighten both hex set screws in these lugs and trim off any excess cable.

5. Locate the RPU padlock and lock the RPU cabinet. It should be locked whenever leaving the site.

CENTRAL PROCESSING UNIT AND TERMINALS

Equipment installation described in this section includes the CPU cabinet with its equipment, computers (terminals), video terminals, printers and the optional CPU radio antenna.

A short section is included on the various CPU to RPU and CPU to terminal communications methods. These include radio telemetry, standard autodial phone lines, and DC continuity leased or DC continuity hardwired lines. The radios must be licensed and the phones lines installed prior to system commissioning.

Placing the CPU Cabinet and Equipment

The CPU cabinet location should be shown in the system plans and must be installed:

1. out of direct sunlight
2. in an environmentally controlled room, 60°-90° F
3. in an easily accessible location, doors must be clear to swing open
4. next to 2 grounded 120 VAC, 60 Hz, 15 Amp receptacles
5. within 100' (maximum cable distance) of optional CPU radio antenna or next to optional hardwire lines leading to the remote CPU radio location
6. next to the RJ11C modular phone line jack(s) for CPU communications
7. next to optional leased or hardwired line termination point(s) for CPU communications.

The CPU cabinet should be uncrated and moved to the location where you will be operating your SCAN equipment. Unpack the CPU equipment and check for any shipping damage. Do not attempt to install any of this equipment and do not place it in the cabinet. The commissioning technician will do that as part of his trip.

When unpacking any CPU equipment keep the manuals and accessories with each piece of equipment and store empty cartons in a dry place. During the system commissioning, SSI personnel will advise you on what to keep.

Mounting and Wiring the Optional CPU Radio Antenna

The CPU radio antenna will only be required on systems that communicate to the RPU(s) by radio signal. Disregard this section if RPU communication is not via radio. The directions here describe mounting the Hustler G7-150 omni-directional antenna. If another antenna is to be mounted, use these instructions as guidelines.

WARNING: Installation of this product near power lines is dangerous. For your safety, carefully follow the installation directions supplied with the antenna.

The CPU radio antenna must be mounted within the 100' coaxial cable distance of the CPU radio and not higher than 20' above ground level. From the antenna mounting location there should be a clear view to all RPU locations.

If the CPU cabinet is further than 100' from the CPU antenna, something other than a standard coaxial cable connection must be used. One alternative is a "DC remote". This unit allows the radio and power supply to be placed at a remote location outside the cabinet, but still within a cable distance of 100' from the antenna. A 4 conductor, #18 gauge, shielded cable (not supplied by SSI) is installed between the radio and cabinet. Additionally a grounded, 120 VAC, 60 Hz, 15 Amp receptacle must be provided for the radio power supply. If the cabinet to antenna distance is in the range of 150' to 350', 1/2" Heliax cable is another alternative.

See Hustler Antenna Assembly Instructions, Appendix D.

1. Locate and check the Hustler antenna package contents against the pre-packaged instructions to be sure all the parts are included. Shipped attached to the N type connector of the antenna is a PL-259 adaptor plug. This plug is not in the antenna instructions but is supplied by SSI.

2. Per instructions attach the four radials to the base section by inserting the four screws through the plate and the radials. Then thread them loosely into the cast aluminum base. Align the radials and tighten the screws firmly. Add the plastic yellow caps to the ends of the radials.

3. Adjust to length and assemble the vertical radiator sections to the base section per instructions.

4. For antenna mounting, 2 U-bolt clamps are provided for attaching to a 1" to 1-3/4" diameter vertical pipe. Mount this pipe section (not supplied by SSI) securely into the ground or the building structure. Clamp the antenna to the pipe and tighten the U-bolts securely.

5. Ground the mounting pipe to a single 10' x 1/2" copper clad ground rod using a heavy gauge wire, not supplied by SSI.

6. Plug the coaxial cable from the CPU radio into the PL-259 adapter on the antenna. Run the other end of this cable into the building, making sure to waterproof the cable entrance.

7. Continue running the cable inside building ceilings, etc., back to the CPU cabinet. Leave any excess cable unconnected and spooled in the bottom the cabinet.

Placing Terminals and Printers

The system will have one or more of the following terminals to display system information; Wyse-60 or Compaq 386S. Each terminal will usually have one of the following printers: HP Color PaintJet, Okidata 182 Plus, or IBM Quietwriter. Some terminals will include external modems such as the Hayes Smartmodems, Motorola UDS, or MultiTech.

The various terminal and printer interconnect cables are device labeled on the connectors, set them aside until the system commissioning. The Panasonic portable terminal/printers may also be included and will be programmed during the commissioning.

Please refer to the system plans for terminal, printer and modem types and locations. If you are in doubt about a terminals suitable location or method of communication to the CPU, contact the SSI Technical Sales Support. The terminals, printers and modems should be:

1. in an environmentally controlled room, 60°-90° F
2. at a centralized, easily accessible, desk type location
3. next to a 120 VAC, 60 Hz, 15 Amp receptacle for each device

Additionally:

1. The terminal, if hardwired, must be within a 50' cabling distance (maximum RS232 cable distance) of the CPU cabinet, for communication to the CPU.
2. The terminal, if the remote autodial type, must be next to the RJ11C modular phone line jack for dial out communication to the CPU.
3. The terminal, if the DC continuity leased line or as DC continuity extended hardwire type, must be next to the leased line or cable termination point for communication to the CPU.
4. Any printer used with an IBM must be within 15' (maximum cable distance) of its IBM.
5. Any printer used with an terminal must be within 50' (maximum cable distance) of the terminal.

When unpacking terminals and printers, keep the manuals and accessories with the equipment and store the empty cartons in a dry place. During the system commissioning SSI personnel will give advice on what to keep.

Do not hook up or power up any of this equipment without contacting SSI Technical Sales Support, as the system warranty may be affected.

<u>CPU to RPU and CPU to Terminal Communications Methods</u>

This section explains how the CPU communicates to both RPUs and terminals. Most systems use a combination of the 4 methods below and should be designated on the system plans. Please consult SSI Technical Sales Support if you have questions.

1. <u>Radio telemetry</u> is used only between the CPU and the RPU. Only one radio frequency is required per system, but it must be licensed for each radio location. Important Note: The system FCC radio license must be applied for by the agency that will own and operate the system. To apply, the agency submits coordination and application forms plus a fee to APCO, who then applies to the FCC for the license. This process always takes at least 6 weeks, so it should be done early in the installation. SSI will not commission any system without a radio license, since it is a Federal offense to operate the system without it. Radio license application assistance is available from SSI Technical Sales Support.

2. Autodial phone is used between the CPU and the RPU, and/or the CPU and a terminal. A Hayes 1200 baud modem is always required at both ends of the phone circuit for RPU to CPU communications. MultiTech 9600 baud modems are used at both ends of the circuit for terminal to CPU communications. It involves ordering from the local phone company a separate phone line for each device with the following specifications (to give the phone company):

   - the FCC registration number and the ringer equivalence number of the modem is found on the label on the underside of the modem.
   - the modem requires a standard RJIIC modular jack
   - the modem requires a touch tone voice grade line with an unlisted phone number.

3. DC continuity leased or DC continuity extended hardwire lines provide the communication between the CPU and the RPU, and/or the CPU and a terminal. Both leased line and hardwire methods are electrically the same. The leased line is normally rented on a monthly basis from the phone company and the hardwire is installed permanently between the 2 devices communicating. A separate modem is required at both the CPU and terminal locations for each terminal. Specifications for these lines are as follows (to order from the phone company or install):

   - the CPU to RPU lines can be either 2 or 4 wire
   - the CPU to terminal lines must be 2 wire
   - all lines must be the DC continuity type, with unconditioned ones working the best
   - all extended length hardwire 2 or 4 wire lines will work up to a maximum distance of 2 miles.

4. Microwave communication channels may be used for both CPU to RPU and CPU to terminal communications. The following specifications apply to these channels:

   - The customer supplied microwave channel will be voice grade, 4 wire, and full duplex, except where connected to MultiTech modems which require 2 wire full duplex.
   - Audio levels will be -10 dbm from the SCAN equipment and -23 dbm into the Scan equipment.
   - Frequency response is to be 300 - 3000 hz, plus or minus 5 db.
   - Both input and output impedance of the SCAN equipment is 600 ohm. Modems and RPUs are a balanced load and the radios are unbalanced (one side of the line is grounded).
   - A contact closure for signaling is provided from the SCAN equipment. SCAN equipment requires customer supplied contact closure for signaling. No battery voltage is supplied or required by SCAN equipment. NOTE: The radios used with SCAN systems have one side of the contact leads grounded. RPUs provide a true isolated contact closure.
   - Any attenuation pads, amplifiers, isolation/matching transformers, baluns, battery sources, or hybrids required to meet these specifications are to be customer supplied.

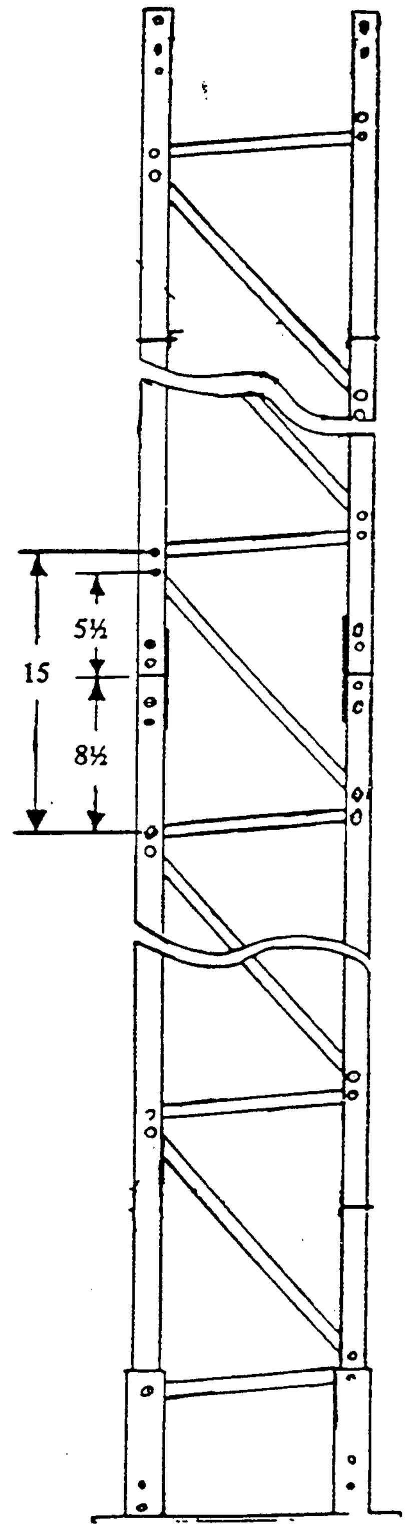
5. RS232 direct connect line is used between the CPU and a terminal. The maximum distance between the CPU and a terminal is 50'. This RS232 cable with connectors is supplied by SSI.

READ CAREFULLY

THEN PLAN YOUR INSTALLATION PROCEDURE CAREFULLY

Locate tower site. Maintain safe distance from power lines. At least one and one-half to twice the height of tower and antenna is a safe distance, since any contact with power lines can be fatal to you!

All tower installations should be grounded per local or national codes. All towers should be installed by trained and experienced personnel and should be inspected by qualified personnel at least twice a year.



FIXED BASE - FB-13 or FB-18: When a fixed, non-hinging base is desired, the FB-13 or FB-18 serve as both the concrete footing section as well as the socket for the first section of tower. Locate tower site. Dig appropriate size hole as found in chart. Bolt three legs of base together and then bolt to first section of tower prior to setting in hole. The base assembly and first tower section should be leveled, plumbed, and temporarily guyed or braced while pouring the concrete. Check tower to assure that it is plumb and level after pouring concrete. Crown the top of the concrete slightly to prevent water accumulation. The steel portion of the base legs should extend about nine inches from top of concrete so that aluminum tower sections never come in contact with concrete directly.

TOWER CONSTRUCTION - M-13 or M-18: Separate and count all pieces - three angle side members, 24 short braces, 24 long braces, three short angle joint clips, 120 bolts and nuts. Lay out three side angles so that blue marked ends are together. These ends are always the tower ends that point down. Bolt all cross braces (tubes) to side angle members. Do not tighten bolts until all braces are in place. Then systematically tighten all short braces, then all long braces. It is handy to use a 7/16 nut driver, air or electric wrench. Make sure square on carriage bolt is seated on outside face of tower and bolts torqued to nine foot pounds. After sections are completed, they can be bolted together using short angle joint clips. Here again, make certain bolt heads are seated and properly torqued. Take care that joining tower surfaces are flush.

TOWER ERECTION: Towers less than 50' may be hinged into verticle position with the help of several good men. Be cautioned as to exerting unequal stress on tower legs so as to reduce stress, twist and damage to tower. After tower is erected, replumb tower with main leveling studs. In some cases, it may be preferred to hire a professional tower erector.

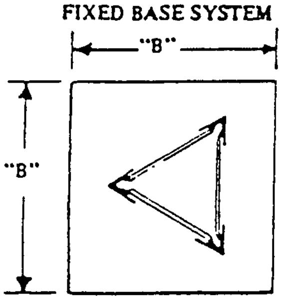
Model M-13 "A" = 3' 9" "B" = 33"

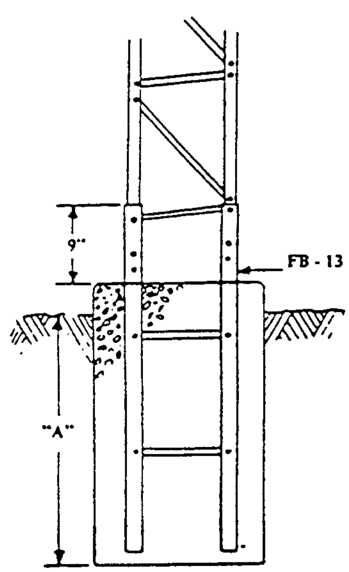
Cubic Yards concrete Required = 1.05

NOTES:

1. Concrete, 3000 psi Min. Ult. strength
2. Foundations designed for 2000 psf soil.
3. Loosen hinge bolts before hinging.
4. It shall be installer's responsibility to provide structurally adequate supports for guy wire anchors.
5. It may be necessary to secure the services of a local engineer to determine that installation complies with local building codes.
6. All tower installations should be grounded per local or national codes.

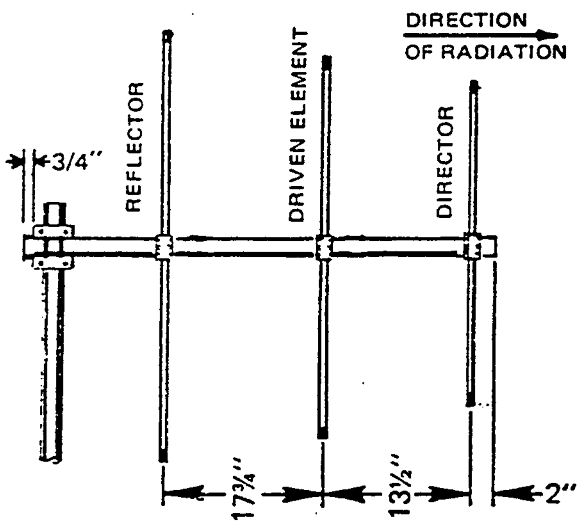
FIXED BASE SYSTEM



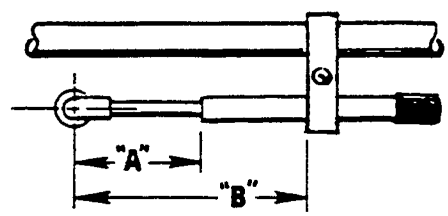


The antenna must be mounted so the elements are vertical. Position the gamma feed down (below the boom) and adjusted to the the dimensions shown. Use silicon grease compound on the threaded portions of the antenna prior to assembly to protect from weather and ease future disassembly. Locate the proper element spacing by measuring and marking the boom, starting with the director 2" from the end of the boom. Assemble the driven element and gamma feed to the boom using the brackets and hardware supplied (Fig. 1). Assemble the director and reflector to boom, an equal length on each side of the boom, using brackets and hardware. Slide the plugs into the end of the boom.

3 ELEMENT SPACING

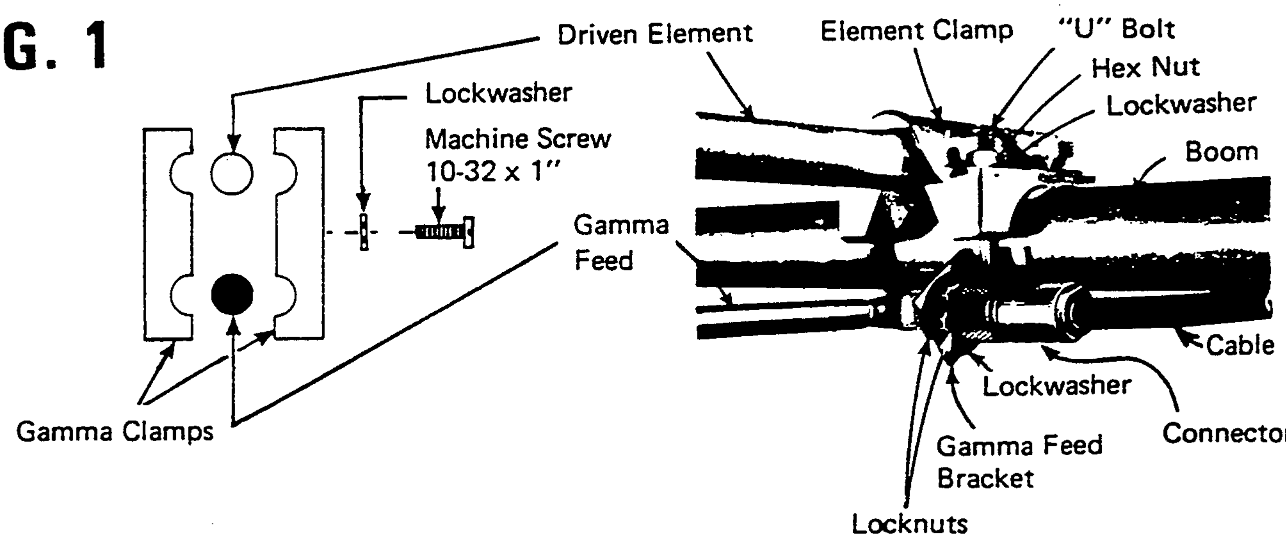


GAMMA FEED



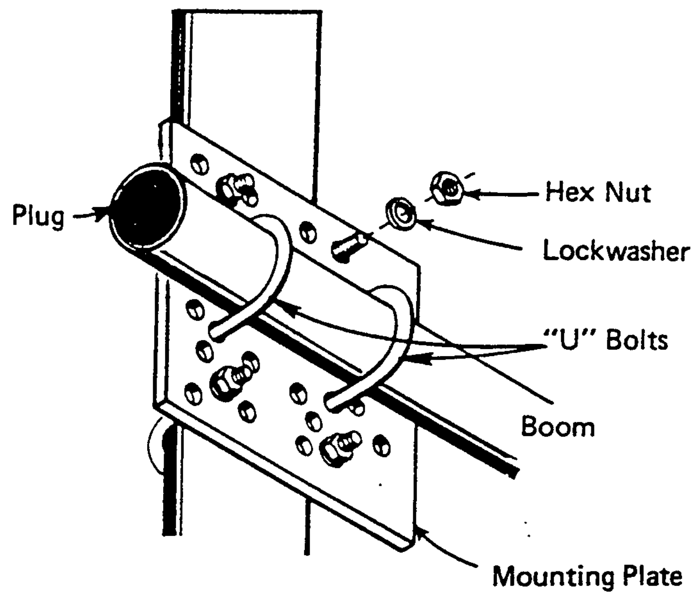
A = 1 3/4"
B = 4"

FIG. 1



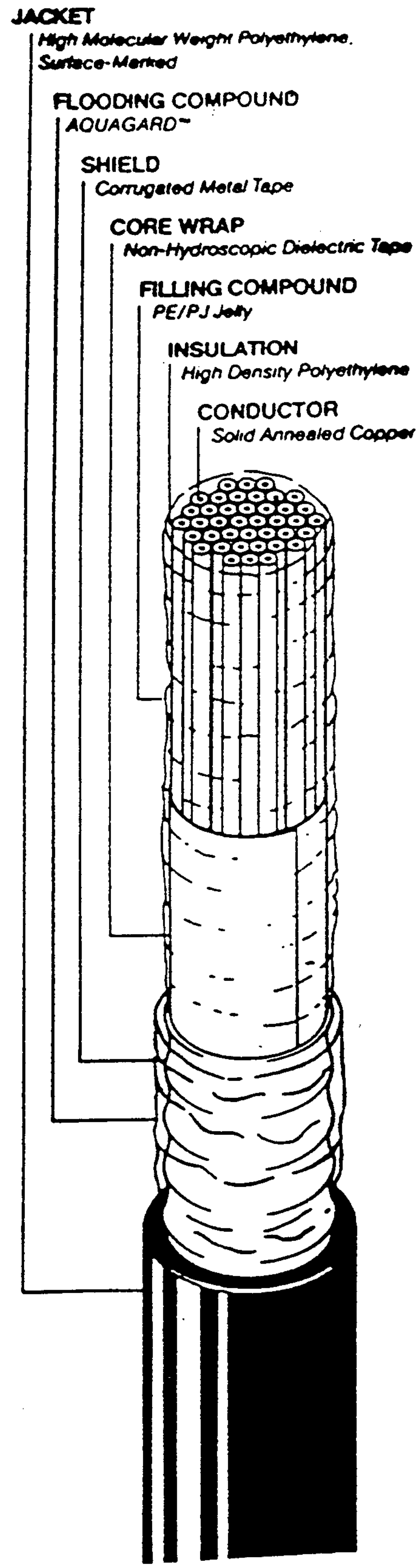
Mount the assembled antenna to the stub using the mounting plate and hardware provided (Fig. 2). DO NOT SHORTEN BOOM - Use the full length supplied. Position the mounting plate with the edge 3/4" from the end of the boom. Connect the cable to the connector adapter.

FIG. 2



Filled Telephone Cable Type PE-39

For use in extending Surface Sensor and/or Sub-Surface Temperature Probe inside ducting or direct buried installations. This construction provides an extra protection of filling material which prevents moisture migration within the cable. Aluminum shield is recommended by SSI.



Cable Specifications:

19 AWG, 6 pair, approximate O.D. is .51", PP or PE insulation, PE jacket, duct or direct burial

The 3 shield types include:

1) Aluminum:
Approx. cable weight 151 lbs/M' for .008" aluminum shield

2) Copper:
Approx. cable weight 168 lbs/M' for .005" copper shield

3) Gopher Resistant:
Approx. cable weight 174 lbs/M' for gopher resistant shield (Cable #BJF-GR)

Electrical Characteristics:

Max conductor resistance @ 20°C (68°F)
  46 Ohms/mile
  8.7 Ohms/M ft.
Max conductor resistance unbalance
  0.2 Ohms/M ft. avg
  0.6 Ohms/M ft. individual pair
Avg mutual capacitance @ 1 kHz
  .063 ± .007 mfd/mile
Max capacitance unbalance @ 1 kHz
  Pair to pair, 100 pf/M ft
  Pair to shield, 250 pf/M ft
Min rms output to output far end cross talk
  loss @ 150 mHz 73 db/M ft.
Dielectric strength for 3 seconds
  conductor to conductor volts, min 7,500 vdc
  conductor to shield volts, min 15,000 vdc
Nominal attenuation @ 1 kHz 1.27 db/mile
Bend Radius 18"

The Hustler antenna should be located within 100 feet of the CPU cabinet.

WARNING: Installation of this product near power lines is dangerous. For your safety follow the installation directions carefully.

Assembly Instructions

1. Check the package contents against the illustration found inside the box to be sure all items are included.

2. Refer to Figure 1 and attach the 4 radials to the base section. Insert the four #5180-5 screws through the #5357-7 plate and through the #3553-15, or -16 radials then turning it 2 or 3 turns into the case aluminum base. When radials are properly aligned, tighten down the screws. Add the yellow caps to the ends of the radials.

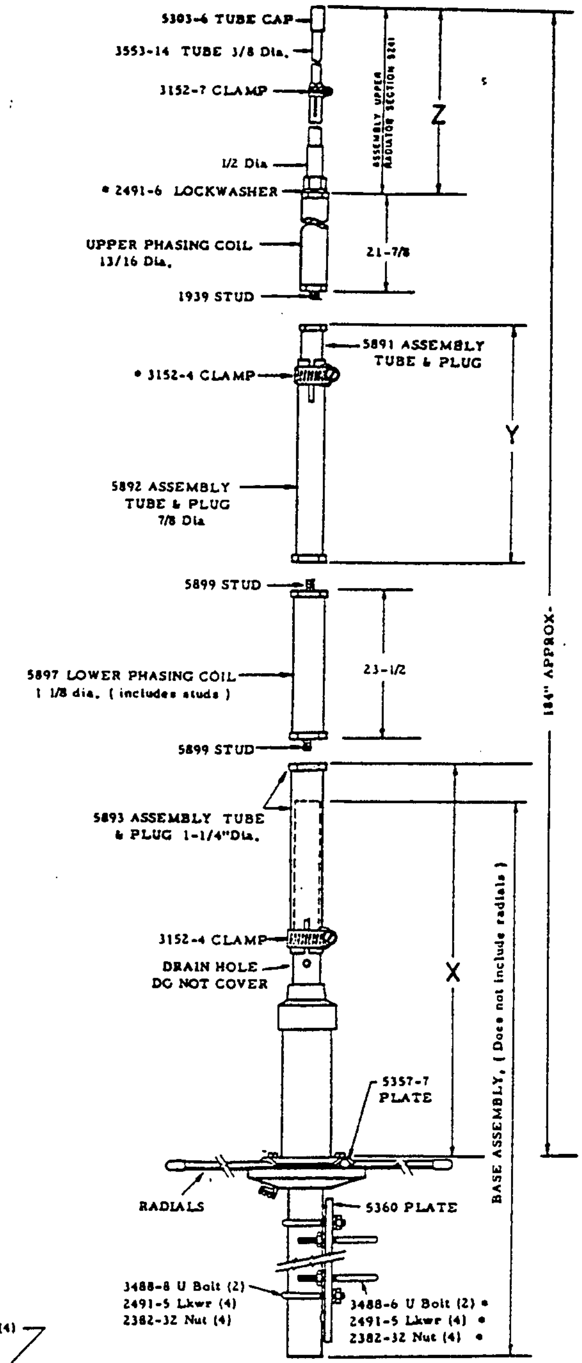
3. Attach the vertical radiator sections to the base section per illustration included with antenna.

4. A 1 to 1-3/4" diameter mast can be used with the antenna. Two u-bolts are supplied to mount the antenna to your mast.

Antenna Model:	G7-150-4
Frequency Range:	167-184
Frequency MHz:	171.0
Part Number:	3553-16
Length:	18-1/4"
Phasing Coil P/N:	Upper Coil 5240-5
	Lower Coil 5897-4
	Base Assm 6139

Dimensions of Adjustable Sections:

"X" 39.000"
"Y" 37.500"
"Z" 42.750"



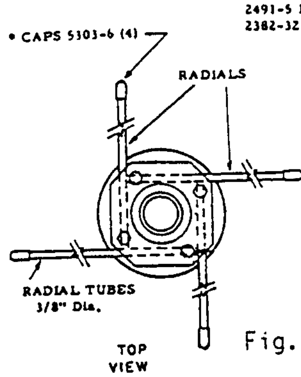
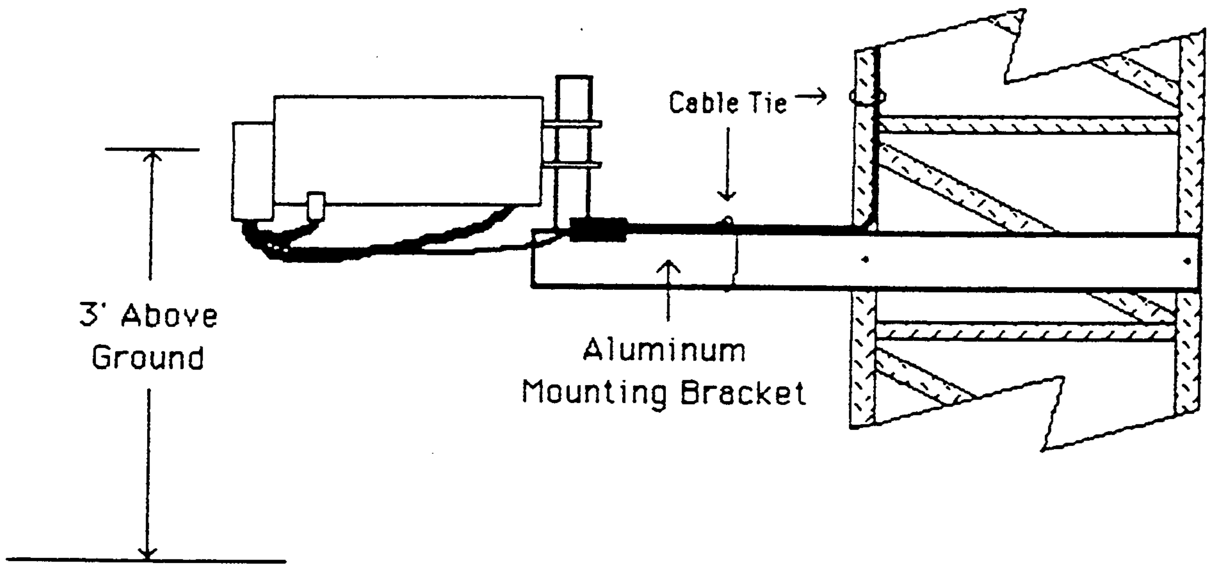


Fig. 1

Appendix E - EXPERIMENTAL LOW LEVEL HYDROMETEOR DETECTOR

If an experimental low level hydrometeor detector is included in your SCAN system, mount it as follows:

1. Use the pre-drilled mounting bracket as a template to drill two 13/32" mounting holes in the tower legs. Secure the bracket to the tower with 3/8" mounting hardware.
2. Secure the detector to the stub at the end of the mounting bracket with the U-bolt clamps provided. Make sure these clamps are not over tightened as the frame of the detector will be deformed.
3. Run the sensor cable along the top of the mounting bracket and up the closest tower leg. Secure the cable every 18" with weatherproof cable ties. Drill a hole in the bottom of the RPU cabinet and install an appropriate rubber bushing strain relief connector, not supplied by SSI. Run the cable through the connector and leave the excess cable spooled inside the RPU cabinet.



1.0 The following terms shall have the following meaning:

1.1 "System" shall include the following components:

1.1.1 "Sensing Devices" shall mean devices, including Sensors as defined in 1.1.2 below, supplied by Surface Systems, Inc. ("SSI *") which collect, observe or measure Site Specific Information.

1.1.2 "Sensor or Sensors" shall mean surface sensors, sub-surface temperature probes, and the cable supplied attached to said surface sensors and sub-surface temperature probes, supplied by SSI.

1.1.3 "RPU" shall mean Remote Processing Units supplied by SSI for collection, processing and transmission of input from the Sensing Devices and from sensors or devices provided by Customer or third parties.

1.1.4 "Hardware" shall mean computer hardware and peripherals supplied by SSI, including Central Processing Units ("CPU"), for the collection, transmission, processing, storage, dissemination and display of input from the Sensing Devices and from sensors or devices provided by Customer or third parties.

1.1.5 "Software" shall mean SSI proprietary software, and all related documentation, in any way related to the function or operation of the System, including but not limited to all programs and all algorithms consisting of instructions embodied in machine readable form, in Read Only Memory or any other data storage media; Software shall not include any source or object code for the System.

1.2 "Site Specific Information" shall mean all atmospheric, pavement surface, sub-surface and other parameters which can be measured or sensed by the Sensing Devices and sensors or devices provided by Customer or third parties.

2.0 SSI warrants that the components of the System, except Sensors which shall be covered by the warranty in Section 6 below, will conform in all material respects to SSI's standard specifications, if installed, operated and maintained in accordance with SSI's instructions and will remain free from defects in workmanship and material for a period ending ninety (90) days from the date of original shipment from a SSI facility. This Warranty shall not cover any items or equipment identified in Section 14 hereof.

2.1 SSI will extend the ninety (90) day warranty period in Section 2.0 to an eighteen (18) month period from the date of original shipment, if the Customer, prior to the commissioning of the System, installs a standard telephone line at each location of a CPU used in Customer's System and agrees to pay all monthly service charges associated with such telephone line for the term of this Warranty; any telephone lines so provided are for exclusive use of SSI to access and maintain the System.

3.0 SSI's obligation under the Warranty shall be limited to the following:

3.1 SSI may, at its option, provide the Customer with replacement components of the System, and the Customer shall be responsible for its installation or replacement.

3.2 SSI may, at its option, send SSI service personnel to the site of the System, to repair or replace components of the System.

4.0 The Customer shall assist SSI in location of any defects by ascertaining the proper operation of Customer or third party-supplied equipment and services at all locations of System components, including without limitation all sensing devices, commercial power, telephone lines and communication media or equipment.

4.1 Upon notification by the Customer of the existence of a defect in the System, the Customer and SSI will use reasonable best efforts to diagnose the defect. At SSI's request, Customer shall assist with such diagnosis by performing tasks including, but not limited to, resetting System components, visually observing indicators, starting diagnostic programs and checking Customer or third party-supplied equipment and services described above.

4.2 If SSI provides replacement components pursuant to Section 3.1, the Customer shall return the defective components to SSI within 30 days after replacement or SSI shall thereafter be entitled to invoice Customer for the defective components at SSI's then-current prices for new components.

4.3 If SSI provides service personnel for on-site warranty service pursuant to Section 3.2, the Customer will provide at its own expense:

4.3.1 Reasonable access to the System as requested by the service personnel.

4.3.2 Adequate working space and facilities for the service personnel, that are within a reasonable distance from the System to be serviced.

4.3.3 Access and/or escorts into security or otherwise restricted areas where the System is located.

4.3.4 Machinery or equipment (i.e. bucket truck, etc.), traffic control, and/or assistance or escorts to permit SSI to perform warranty service on the System where SSI considers it unsafe for an individual to work unaccompanied, including but not limited to towers, on roadways with vehicle traffic, on or inside or under bridges.

4.3.5 Other reasonable information, assistance and machinery as requested by the service personnel.

5.0 Service under this Warranty pursuant to Section 3.0 and Section 4.0 shall include all expenses and costs incurred by SSI to return the System to normal operating order, including all SSI supplied labor, components, parts, materials, travel, lodging, meals and shipping.

6.0 SSI warrants that Sensors shall conform in all material respects to SSI's standard specifications, if installed, used and maintained in accordance to SSI's instructions, and will remain free from defects in workmanship and material, for the usable life of the System. The Warranty will be null and void if a Sensor ceases to function in all material respects to SSI's standard specifications due to:

6.1 Abnormal physical wear to the Sensors.

6.2 Sensor installation that was not in accordance with the SSI installation manual specifications and drawings.

6.3 Attempts to remove, re-install or change the physical location of a Sensor.

6.4 Damage caused by acts of God including lightning, shifting of the earth, or other natural disasters.

6.5 Damage caused by acts, accidental or intentional, of man or machinery.

6.6 Failure of the Customer to properly maintain the pavement in which the Sensor is installed, including but not limited to repairing cracks around the Sensor and cable saw kerfs.

6.7 SSI's obligation under the Warranty in this Section 6 shall be limited to providing a replacement Sensor for the defective unit. Installation of the replacement Sensor is not provided under this Warranty. For the Warranty period stated in Section 2 and after the installation of the warranty replacement Sensor, SSI will provide any alignment and calibration, which may be required, to return the affected System component to normal operating order.

7.0 SSI warrants that Type V Sensor (extension) cable and splices provided by SSI, shall conform in all material respects to SSI's standard specifications, if installed, used and maintained in accordance with SSI's instructions and good electrical practices, and will remain free of defects in workmanship and material for the warranty period described in Section 2.

*SSI is a Registered Trademark of Surface Systems, Inc.

7.1 Damage and/or repairs to the Type V cable or splices made by persons or entities other than SSI personnel are not covered under this Warranty.

8.0 SSI's obligation under this Warranty with respect to Section 7.0 shall be limited to providing for the repair of the defective Type V cable or splice, or providing replacement cable or splices for the defective Type V cable or splices. Installation of the replacement Type V cable or splices is not provided under this Warranty. For the Warranty period stated in Section 2 and after the installation of the warranty replacement Type V cable or splice, SSI will provide any alignment and calibration, which may be required, to return the affected System component to normal operating order.

9.0 SSI makes no warranty that the System will provide either uninterrupted or error-free data.

10.0 This Warranty shall not apply to System components which have been altered, operated, or maintained in a manner not approved by SSI, or which has been damaged through negligence, accident or misuse.

11.0 Any System components repaired or replaced under this Warranty, except Sensors as stated in Section 6, will be warranted for the balance of the Warranty period.

12.0 SSI may provide reconditioned System components, if in SSI's opinion, the reconditioned components are equal in performance to the original SSI provided System components.

13.0 Any special or specific System component or other component provided by SSI, at the Customer's specific request, which is not a standard component of the SSI System, will not be covered under this Warranty, but will be covered under the specific warranty terms stated in the SSI written proposal, Purchase Agreement or other correspondence.

14.0 The following are not covered under this Warranty:
- 14.1 Electrical or communications work or equipment external to System components.
- 14.2 Any accessories, attachments, other devices or software not furnished by SSI.
- 14.3 Any service or replacement parts necessary because of relocation of System components covered under this Warranty.
- 14.4 Service or replacement parts necessitated by damage caused by acts of God, including but not limited to lightning, wind, flooding, avalanches, and shifting of the earth.
- 14.5 Service or replacement parts necessitated by damage caused by acts, accidental or intentional, of man or machinery.
- 14.6 Labor and expenses or cost of labor and expenses to install or replace any Sensors or any cables attached thereto, covered or not covered under this Warranty.
- 14.7 Installation work of System components or problems related to the installation of System components, if the installation work was performed by persons or entities other than SSI.
- 14.8 Communication media or radio paths that are, or have become, noisy or affected by interference of any kind, which cause unreliable communication due to factors other than the performance or function of the System components.
- 14.9 Interference of any kind to other equipment or systems, which may be caused by the System, if the System is operating in all material respects to SSI's standard specifications.

15.0 SSI reserves the right to charge or invoice the Customer, at SSI's then current prices for replacement System components, labor, travel time, travel and other expenses, for any SSI provided services and System components which are not covered under this Warranty including without limitation, locating and/or correcting problems caused by Customer or third party provided equipment, sensing devices, services, commercial power, telephone lines, communications media or equipment and any items referred to in Sections 7.1, 13 and 14.

16.0 Warranty service will not be provided if, in the opinion of SSI, it is unsafe or impractical to render such service because of: (a) alterations to the System performed by persons other than SSI; (b) connection of the System by mechanical or electrical means to equipment or devices provided by persons other than SSI; (c) System components located in unsafe or hazardous environments; (d) when weather or other conditions make servicing the System unsafe.

17.0 During the term of this Warranty the Customer will have unlimited toll free telephone access to the SSI Customer Service Department.

18.0 All claims for warranty service shall be made prior to the expiration of this Warranty. SSI will honor all warranty claims made during the term of this Warranty, even if the warranty service is provided after the expiration of this Warranty.

19.0 The provision of any services or replacement System components to Customer which SSI is not obligated to provide under this Warranty shall not constitute an alteration or waiver of the terms of this Warranty.

20.0 **EXCEPT FOR THE EXPRESSED WARRANTIES SET FORTH IN THIS WARRANTY STATEMENT SSI MAKES NO OTHER WARRANTIES EXPRESSED OR IMPLIED, INCLUDING THE WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE, WITH RESPECT TO THE SYSTEM OR ANY EQUIPMENT, COMPONENTS, SENSORS, SOFTWARE, DOCUMENTATION, SYSTEM PROVIDED DATA, ANY SERVICES OR TECHNICAL ASSISTANCE OR ANY OTHER ITEM DELIVERED BY SSI.** SSI shall not be liable for and Customer assumes responsibility for all personal injury and property damage resulting from the System.

21.0 In no event shall SSI, its officers, agents, or employees be liable to any person or entity for the loss of profits or for indirect, special, incidental or consequential damages arising out of or related to the performance of the System, even if SSI or its officers, agents, or employees has been advised of the possibility of such damages.

22.0 The Customer shall indemnify and save harmless SSI, its officers and employees from all suits, actions, or claims of any character brought because of any injuries or damage received or sustained by any person, persons, or property on account of operation, use or non-use by the Customer or any third party, of the System or Site Specific Information.

23.0 Representations or warranties that are inconsistent with this Warranty, made by any person including employees or representatives of Surface Systems, Inc. shall not be binding on Surface Systems, Inc. The period of limitations for any cause of action arising out of, based upon or relating to this Warranty is hereby reduced to and shall be a period of one year after such cause of action occurs.

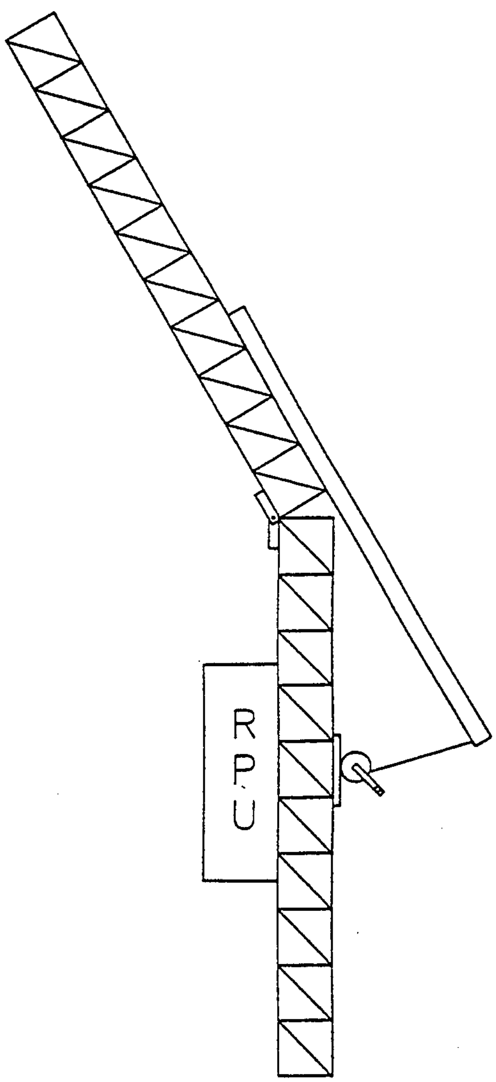
Appendix G - Tower Fold-over Assembly

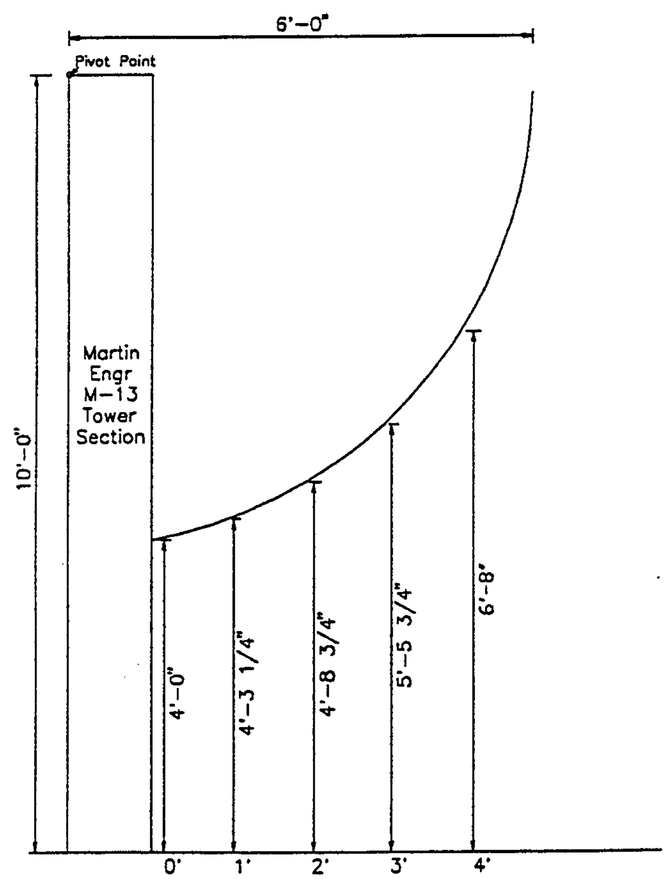
The fold-over assembly permits the installed tower to hinge at the 10' level. This allows the atmospherics mounted on the tower to be serviced by lowering the tower rather than having to reach them from a bucket truck. A hand operated wench lowers the upper section(s) of the tower to ground level for easy access to any components mounted at the top.

The assembly bolts to the tower using existing bolt holes and can be retrofitted to existing installed towers.

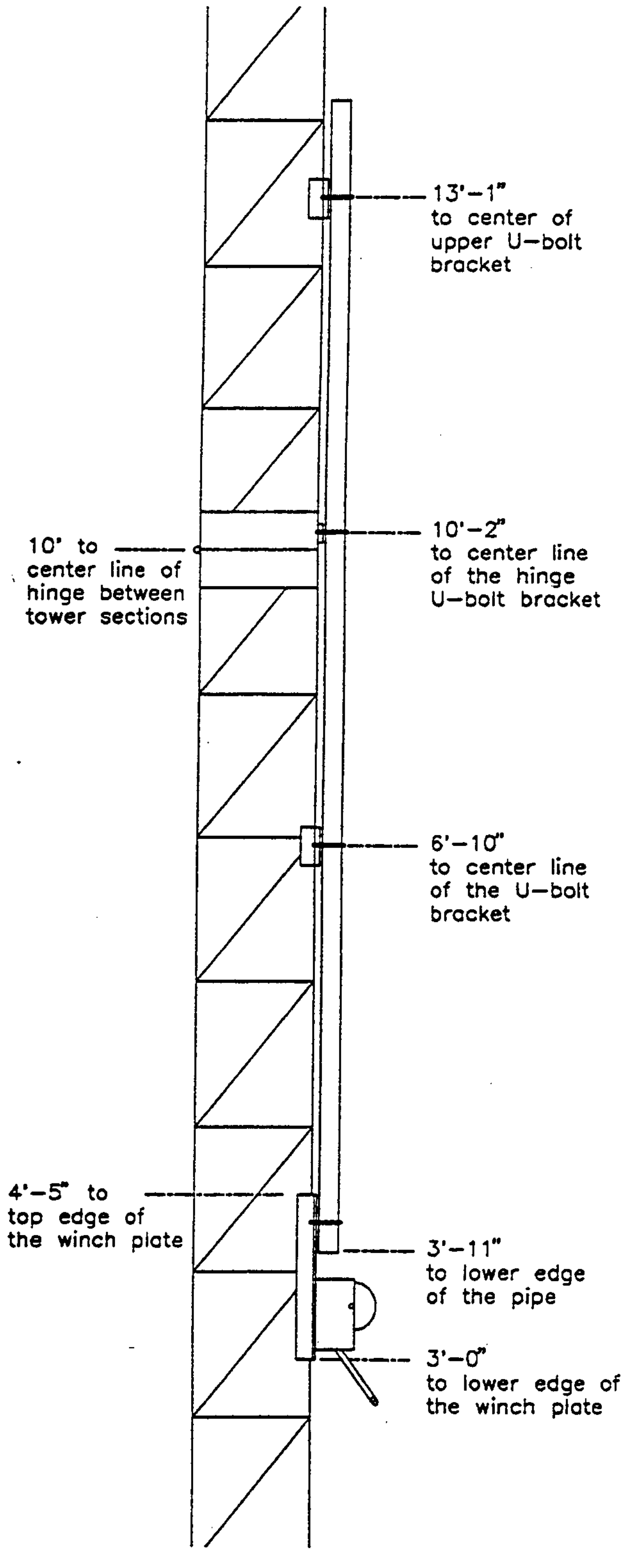
Note: The tower folds OVER the RPU cabinet.

Two legs of the tower are hinged and the third leg separates. A 2" pipe is bolted to this third leg. All parts are either made of stainless steel or galvanized steel.





Clearance Required at Various Distances from the Base



Installation Instructions

1. Bolt the winch to the winch plate using two 3/8" bolts and two 5/16" bolts. Locate the lower edge of the plate 3' from the start of the tower. Remove the six 1/4" carriage bolts from under the winch plate. Bolt the plate to the tower leg using six 1/4" hex head bolts. Drill two 1/4" holes in the tower leg and fasten the plate with two additional 1/4" hex head bolts.

2. Locate the U-bolt bracket at the 6'-10" level. Remove four 1/4" carriage bolts under the clamp. Position the bracket and fasten with four 1/4" hex head bolts. Drill two additional 1/4" holes in the tower leg and fasten the bracket with two 1/4" hex head bolts.

3. The hinge assembly is bolted between the first two tower sections. If there are inside tower clips at the top of the first section, remove them at this time. Locate the hinge assembly on the tower sections and clamp in place so the mounting holes align. Drill through the mounting holes with a 5/16" bit so as to ream out the square holes in the tower leg. Secure the hinge assembly to the two tower sections with twenty-four 5/16" hex head bolts.

4. Repeat step 2 for the U-bolt bracket at the 13'-1" level.

5. Using a U-bolt and saddle placed between the mast pipe and the top mount, attach the mast to the tower. Check the location of the bottom of the mast to make sure the lock tab aligns with the lock hole in the winch plate. Tighten the U-bolt nuts.

6. Install the 3 other U-Bolts in a similar manner.

7. Run the wire rope thru the 1/4" hole in the end of the mast and attach the loose end to the winch with the clamps provided.

APPENDIX H - EXTENDING ATMOSPHERIC CABLES USING TYPE V CABLE

TS5	Type V cable	Atmospheric Sensor Cable
1	Red (Blue)	Black 3 of RH cable
2	Blue (Red)	Red 3 of RH cable
3	White (Orange)	Black 2 of RH cable
4	Orange (White)	Red 2 of RH cable
8	Green (White)	Red of W/S cable
9	White (Green)	Black of W/S cable & Black 1 of RH cable
10	White (Brown)	White of W/S cable & Red 1 of RH cable
11	Brown (White)	Green of W/S cable
13	Blue (White)	Red 2 of Precip cable
14	White (Blue)	Black 1 of Precip cable
15	Gray (White)	Black 2 of Precip cable
17	White (Gray)	Red 1 of Precip cable
Buss Bar	Shield	Shields of Precip, RH, & W/S

Connections are to be made in a rainproof enclosure using a terminal strip. Make sure all atmospheric sensor cables are identified within the enclosure. Cables should enter the enclosure through compression type fittings to ensure the enclosure remains rainproof. The total cable length must not exceed 150'.

The TS5 connection is made inside the RPU cabinet and is for SSI reference only.

RH = relative humidity/air temperature sensor, Thies/SSI model #1.1000.51.551/052-44018-2.5
W/S = Wind Speed/direction sensor, RM Young model #05103
Precip = precipitation sensor, Rudolph model #IRSS88

APPENDIX B

INSTALLATION PHOTOS

Photo 1: RPU Tower Base being constructed by denton workers

Photo 2:

SSI personnel installing electrical hardware

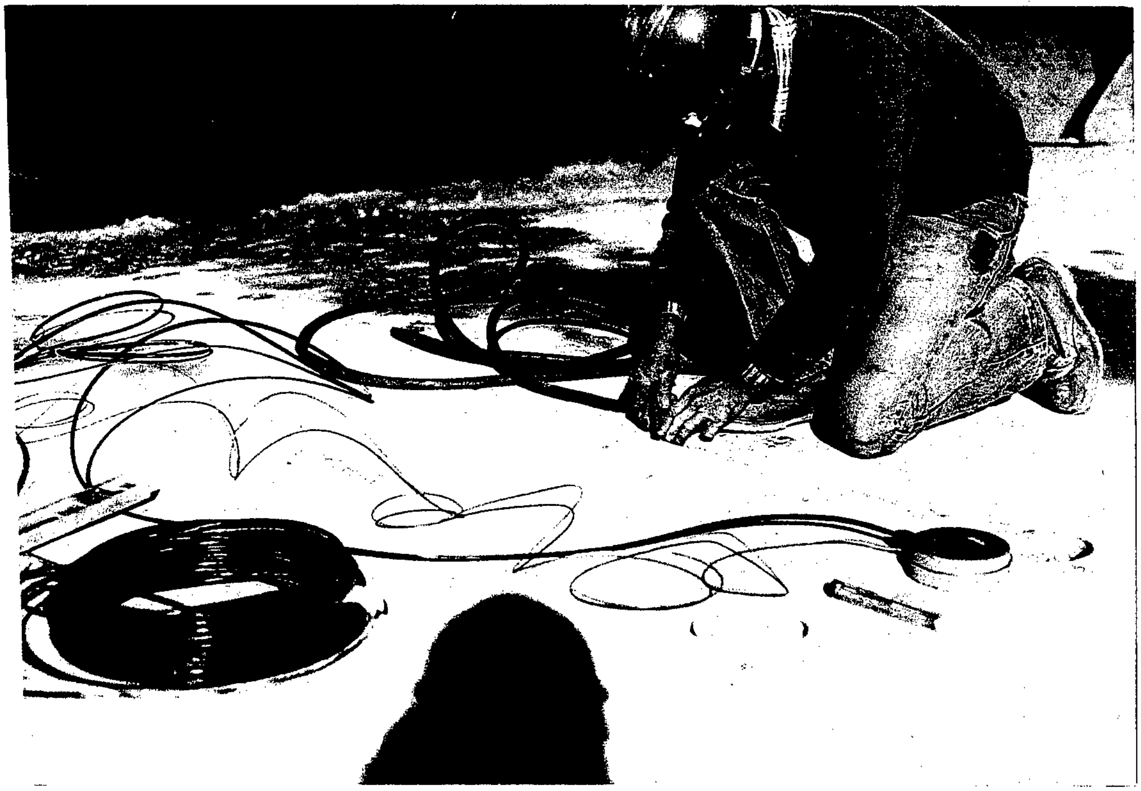


Photo 3: Denton construction worker placing ethafoam rod along saw kerf to embed sensor cable. NOTE: Sensor ready for installation Sensor dimensions: 5 1/4" Diameter, 1 1/4" Thick.

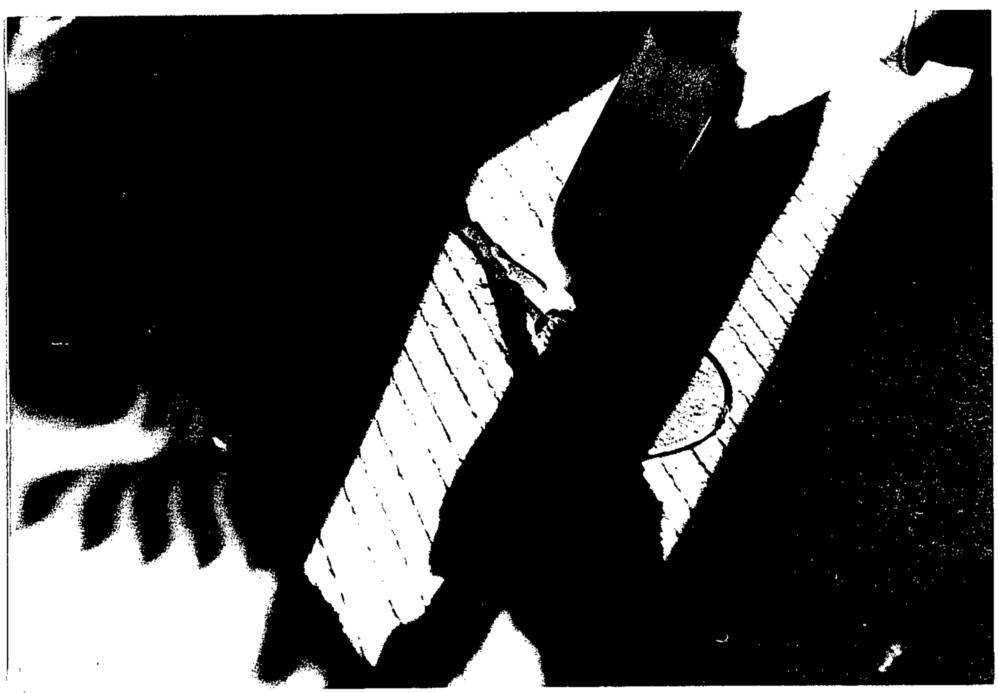


Photo 4: Embedded surface sensor being sealed with epoxy

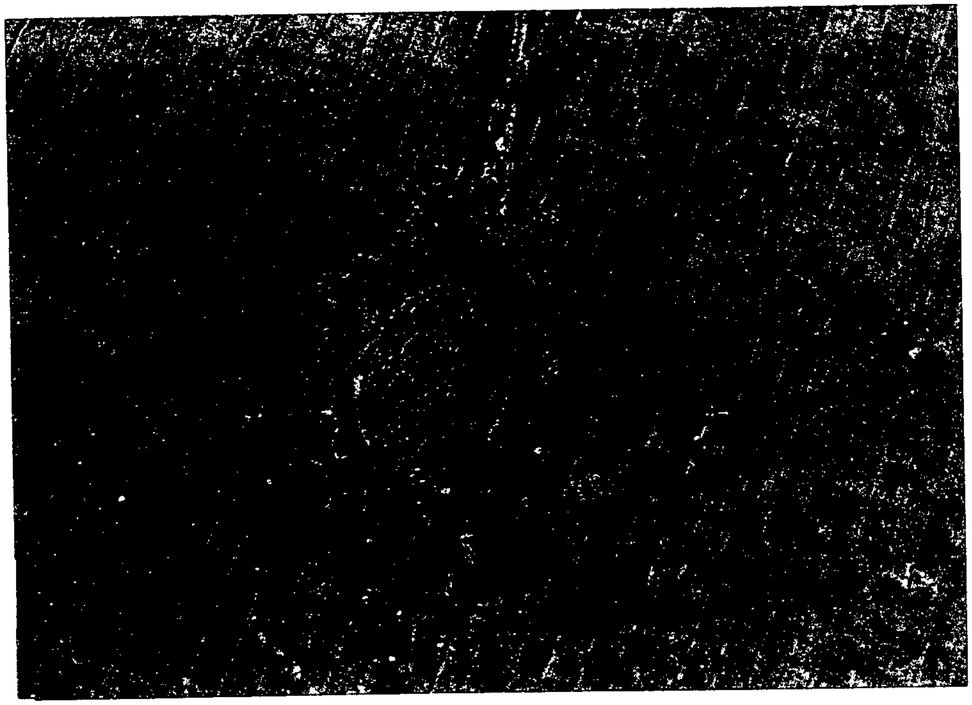


Photo 5: Close-up view of finished sensor installation.
NOTE: Electrodes on the sensor surface.

Photo 6:

Roadway view of sensor and embedded cable along saw kerf.
NOTE: Sensor colored to match pavement.

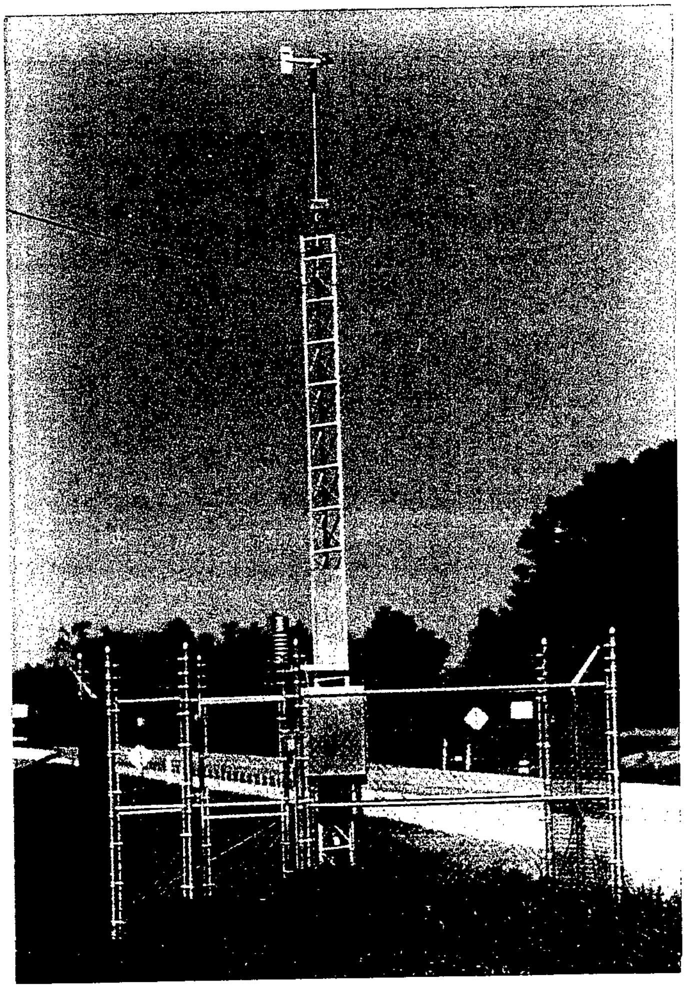


Photo 7:

RPU tower with security fence.

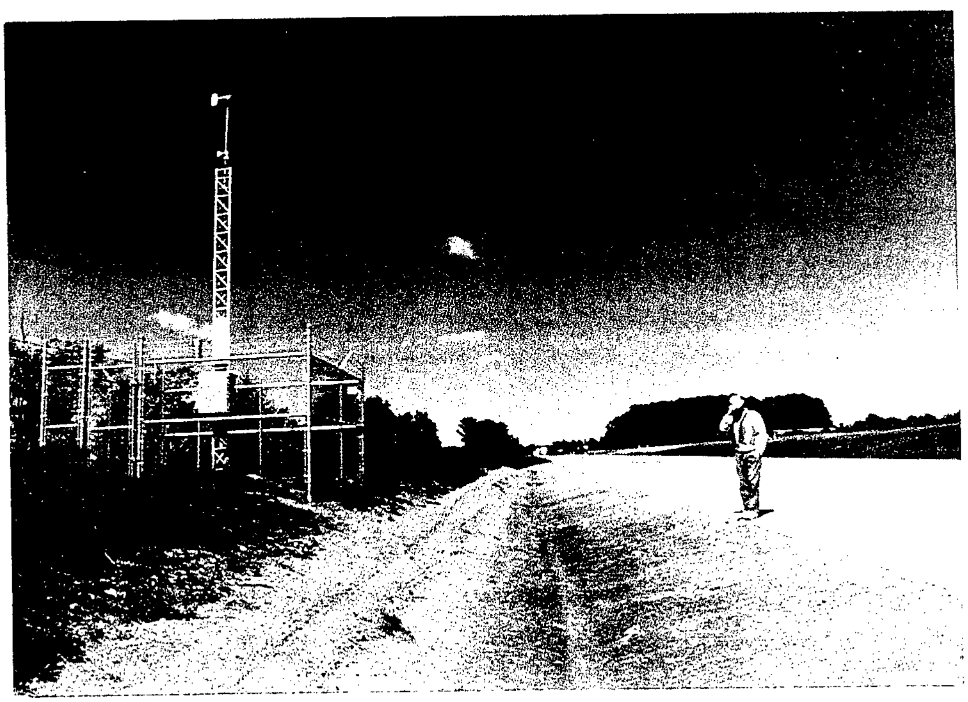
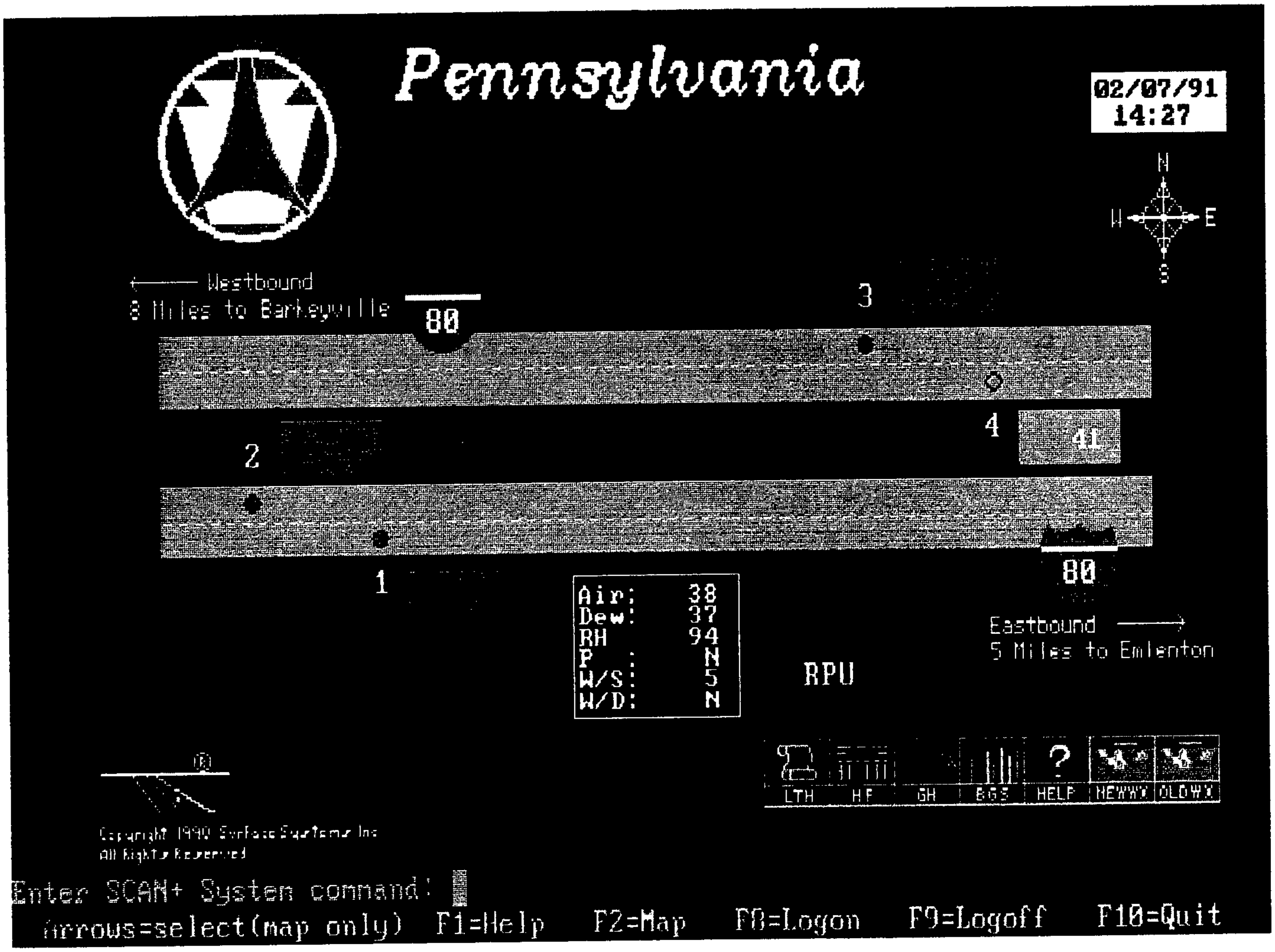


Photo 8: RPU tower and fence in respect to adjacent roadway E.B.L.

APPENDIX C

TYPICAL OUTPUT OF THE SCAN 16 EF SYSTEM


Pennsylvania
02/07/91
14:27
N
W
E
S
Westbound
8 Miles to Barkeyville
80
3
4
41
2
1
80
Air: 38
Dew: 37
RH 94
P : N
W/S: 5
W/D: N
RPU
Eastbound
5 Miles to Emlenton
LTH
HF
GH
BGS
HELP
NEWWX
OLDWX
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Enter SCAN+ System command:
Arrows=select(map only) F1=Help F2=Map F8=Logon F9=Logoff F10=Quit

Long Term History Page

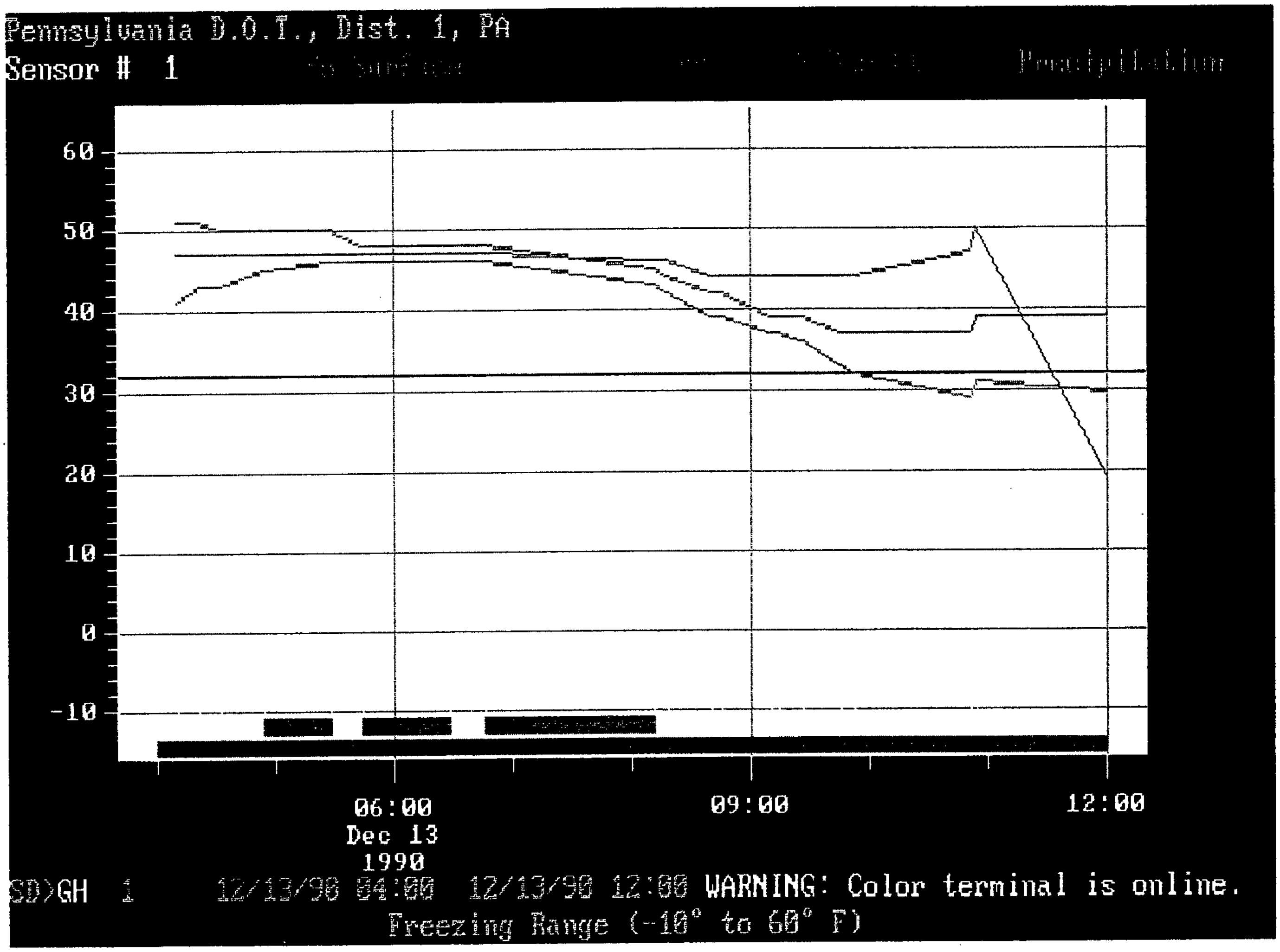
ennsylvania D.O.T., Dist. 1, PA

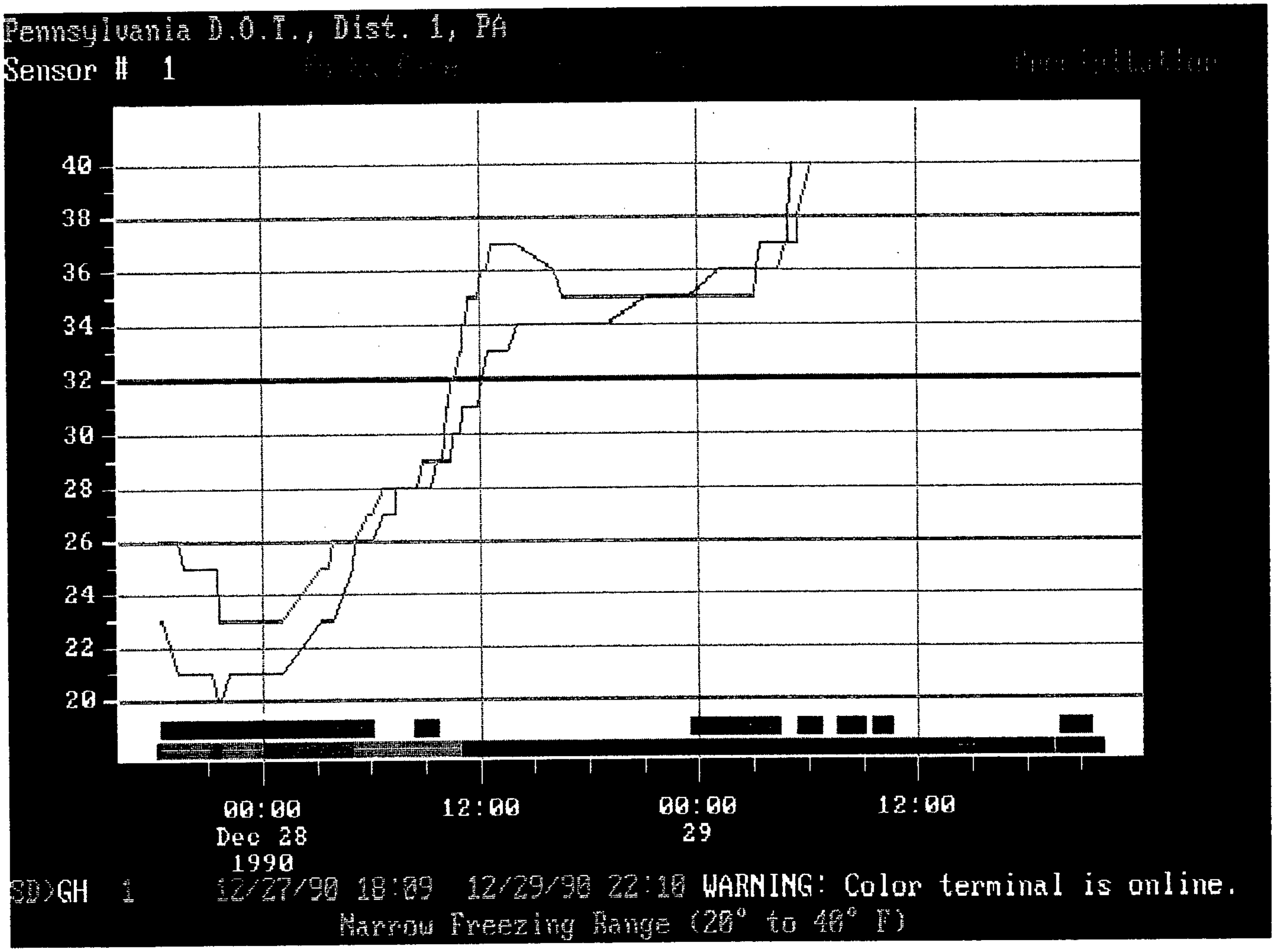
ensor #1

					Temperatures			Wind	
Date	Time	Status	CF	Precip	Surf.	Air	Dew	Dir	Vel
2/27/90	18:09	Snow/Ice Alert	15	Y	27	23	18	SE /	12
2/27/90	18:20	Snow/Ice Alert	45	Y	26	23	19	SE /	13
2/27/90	18:24	Chemical Wet	70	Y	26	23	19	S /	14
2/27/90	18:26	Chemical Wet	70	Y	26	23	19	SE /	12
2/27/90	18:30	Chemical Wet	75	Y	26	23	20	SE /	13
2/27/90	18:56	Chemical Wet	95	Y	26	22	20	SE /	12
2/27/90	19:18	Chemical Wet	70	Y	26	21	19	SE /	13
2/27/90	19:41	Chemical Wet	95	Y	25	21	19	SE /	12
2/27/90	20:30	Chemical Wet	80	Y	25	21	19	SE /	12
2/27/90	20:53	Chemical Wet	95	Y	25	21	19	SE /	9
2/27/90	21:08	Snow/Ice Alert	50	Y	25	21	19	SE /	8
2/27/90	21:11	Snow/Ice Alert	45	Y	25	21	19	SE /	10
2/27/90	21:14	Snow/Ice Alert	40	Y	25	21	19	SE /	9
2/27/90	21:28	Snow/Ice Alert	30	Y	25	20	19	SE /	15
2/27/90	21:34	Snow/Ice Alert	30	Y	23	20	19	SE /	12
2/27/90	21:43	Chemical Wet	85	Y	23	20	19	SE /	14
2/27/90	22:07	Chemical Wet	80	Y	23	21	19	S /	14
2/27/90	22:10	Chemical Wet	75	Y	23	21	19	SE /	12

se arrow keys, PgUp, PgDn, Home, End , or Esc for command line

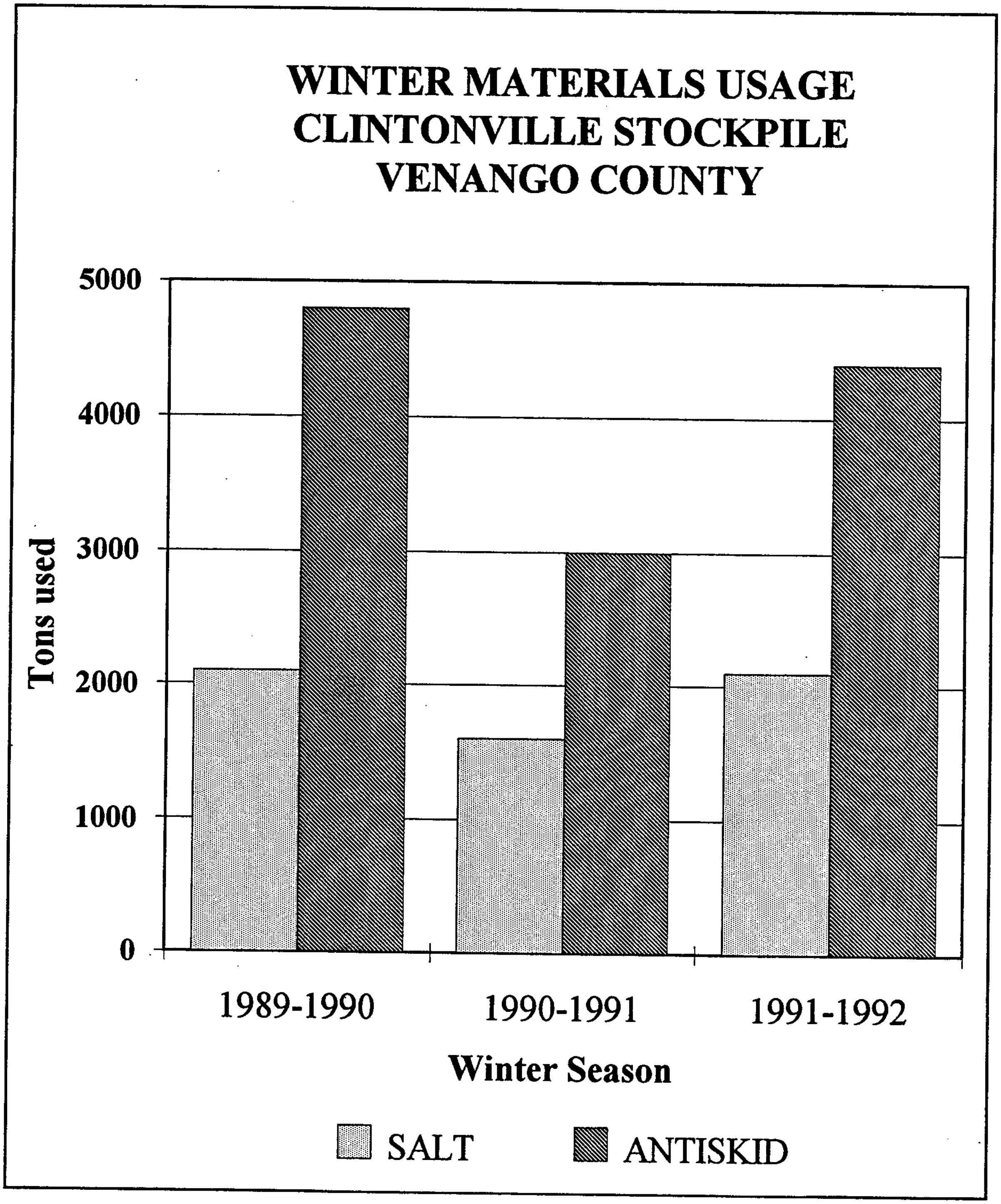
ARNING: Color terminal is online.

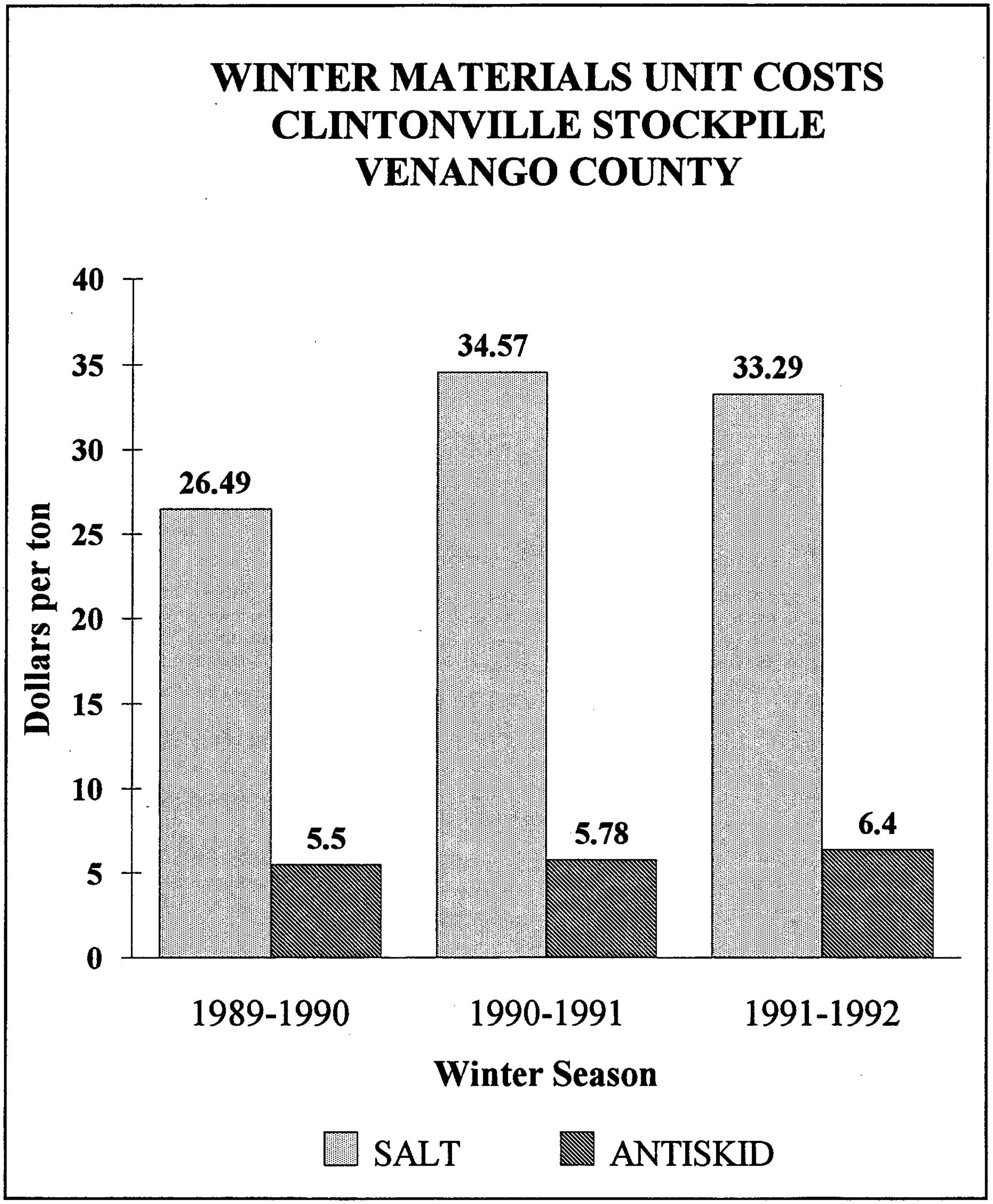

Pennsylvania D.O.T., Dist. 1, PA
Sensor # 1
Precipitation
60
50
40
30
20
10
0
-10
06:00
Dec 13
1990
09:00
12:00
SD>GH 1 12/13/90 04:00 12/13/90 12:00 WARNING: Color terminal is online.
Freezing Range (-10° to 60° F)

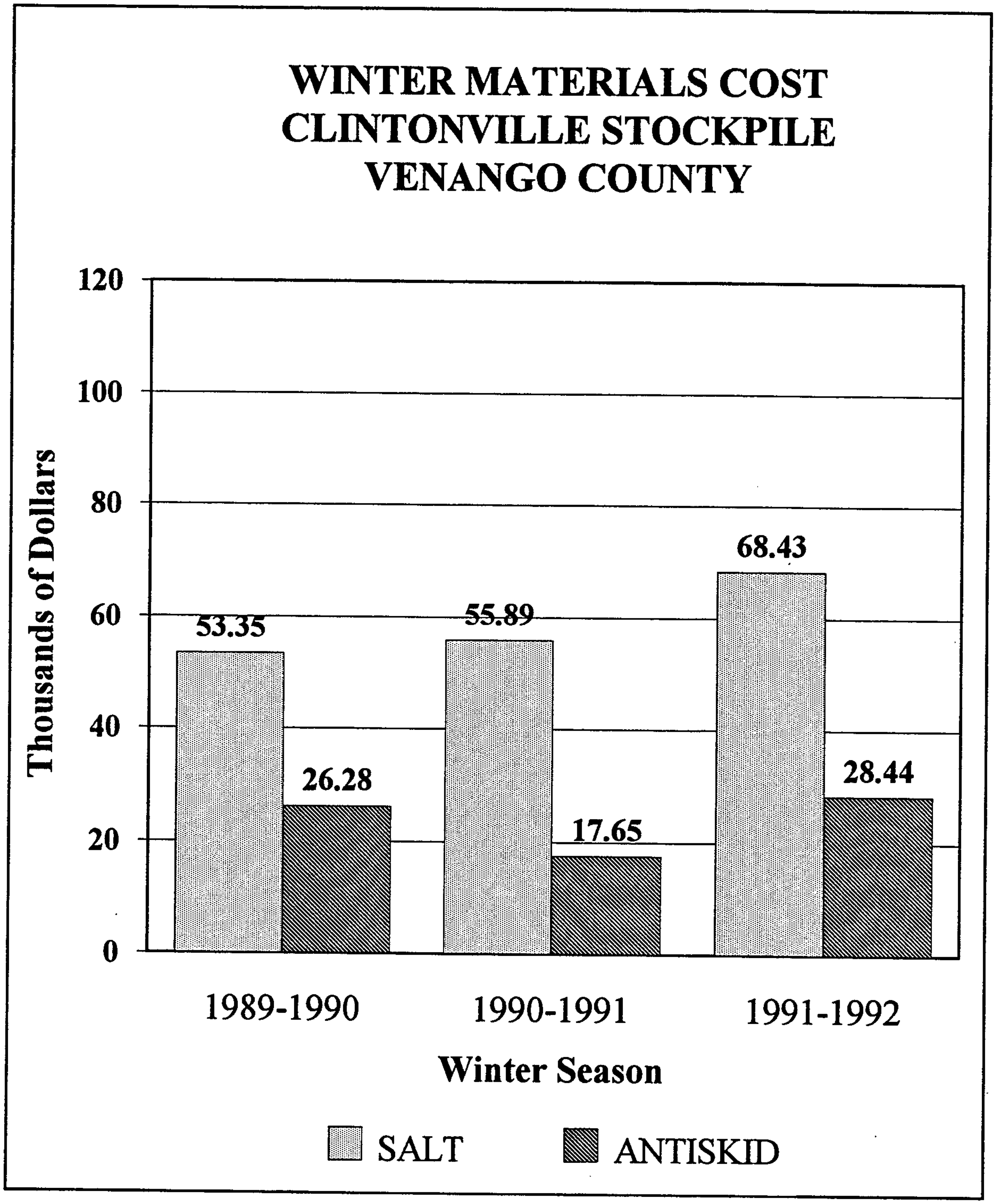

Pennsylvania D.O.T., Dist. 1, PA
Sensor # 1
40
38
36
34
32
30
28
26
24
22
20
00:00
Dec 28
1990
12:00
00:00
29
12:00
SD>GH 1 12/27/90 18:09 12/29/90 22:10 WARNING: Color terminal is online.
Narrow Freezing Range (20° to 40° F)

APPENDIX D

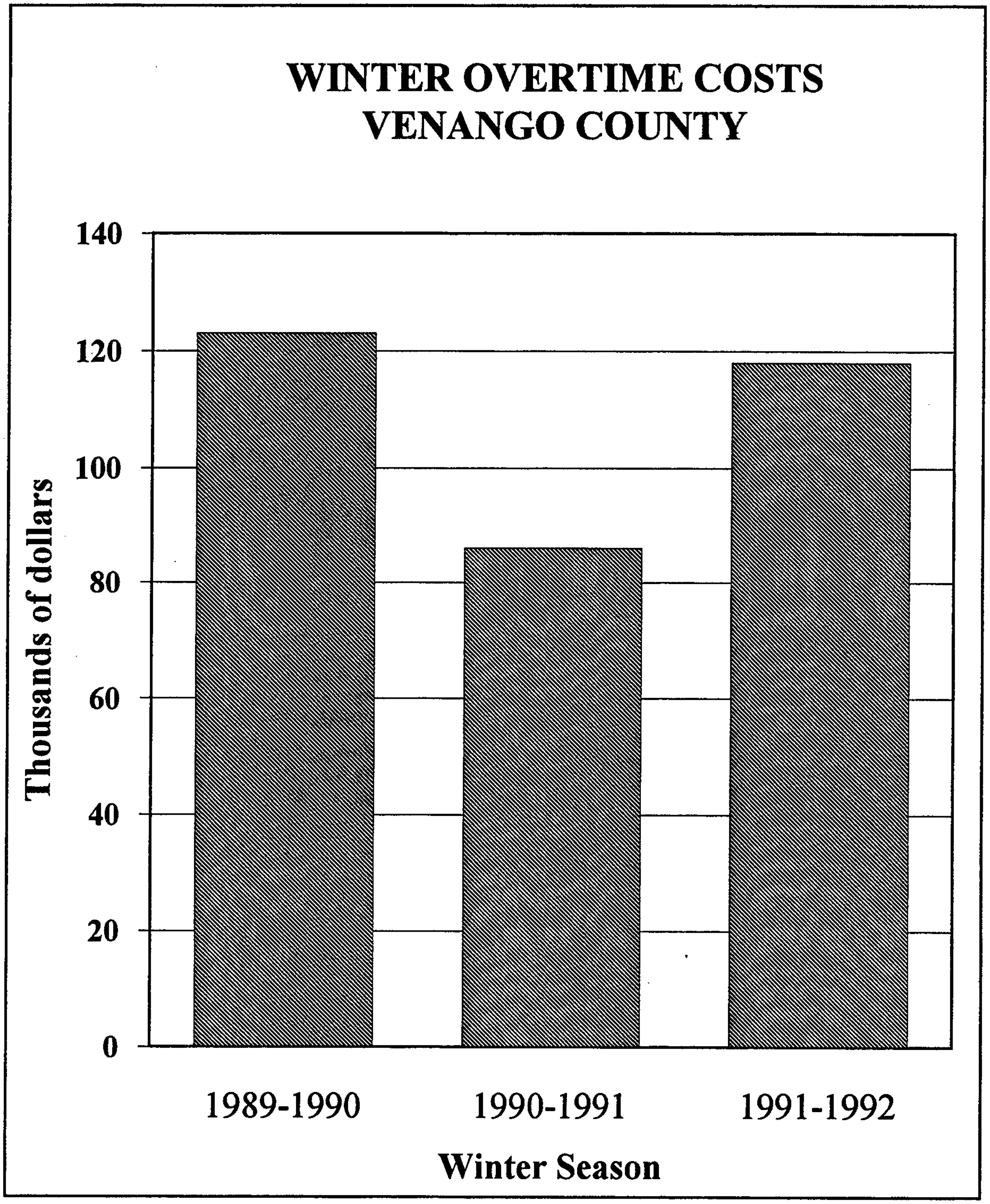
GRAPHS OF MATERIAL COSTS AND USAGE


WINTER MATERIALS USAGE
CLINTONVILLE STOCKPILE
VENANGO COUNTY
Tons used
5000
4000
3000
2000
1000
0
1989-1990
1990-1991
1991-1992
Winter Season
SALT
ANTISKID


WINTER MATERIALS UNIT COSTS
CLINTONVILLE STOCKPILE
VENANGO COUNTY
Dollars per ton
40
35
30
25
20
15
10
5
0
26.49
5.5
34.57
5.78
33.29
6.4
1989-1990
1990-1991
1991-1992
Winter Season
SALT
ANTISKID



WINTER MATERIALS COST
CLINTONVILLE STOCKPILE
VENANGO COUNTY
120
100
80
60
40
20
0
Thousands of Dollars
53.35
26.28
55.89
17.65
68.43
28.44
1989-1990
1990-1991
1991-1992
Winter Season
SALT
ANTISKID


WINTER OVERTIME COSTS
VENANGO COUNTY
140
120
100
80
60
40
20
0
Thousands of dollars
1989-1990
1990-1991
1991-1992
Winter Season

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National Technical Information Service
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